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THE BRITISH JOURNAL OF METALS

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INCORPORATING THE METALLURGICAL ENGINEER

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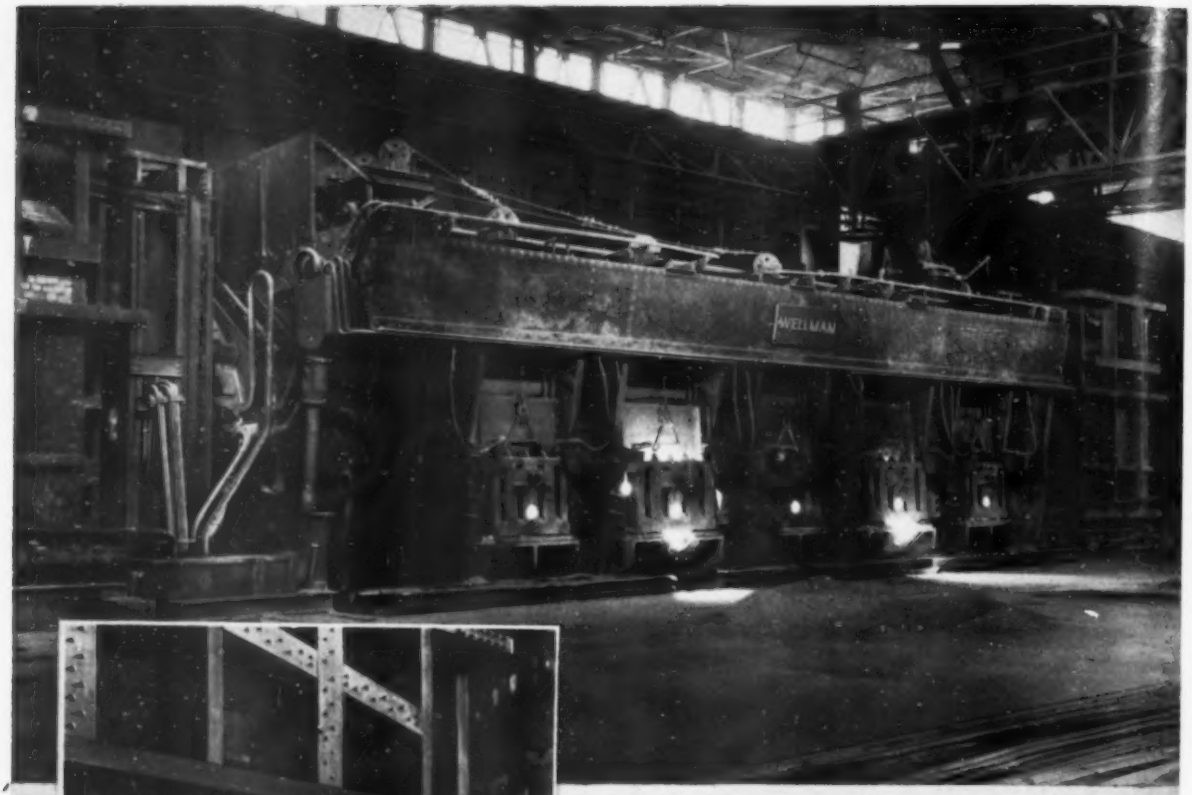

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THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JULY, 1955 Vol. LII. No. 309

Medallic Art and Craft

DURING the last three weeks in June there was held at the Royal Society of Arts House, in John Adam Street, Adelphi, London, an Exhibition of European Medals organised by the Society, with the collaboration of the Royal Numismatic Society and the Fédération Internationale des Editeurs de Médailles. Over 200 medals, representing the finest work of leading designers from 13 European countries, were on show, and, in addition to a small number of coins, the exhibits included an impression from the silver dies of the new Great Seal of England, shown by special permission of Her Majesty The Queen; specimen Royal Tour Medals of 1953; a case of Coronation Medals from the time of King Edward VI, specially prepared for the Exhibition by the Royal Mint; and an exhibit, provided by the Director of the Paris Mint, illustrating the technical processes of medal production.

This was the first occasion for many years, maybe the first ever, in which medals have occupied pride of place at an artistic exhibition in this country. Where they have been given a place at all, they have been shown in such small numbers as to suggest that they are regarded as an inferior form of artistic expression. As Dr. C. H. V. Sutherland, Deputy Keeper of Coins at the Ashmolean Museum, Oxford, pointed out in a paper to the Royal Society of Arts at the start of the Exhibition, the medal is an art-form which is essentially unfamiliar in this country. Unlike a coin, a medal is essentially private and may be restricted to a very small number of copies, in contrast to the vast number of coins produced to a single design. Coins, too, must withstand the wear and tear of circulation without undue damage—a factor which limits the materials and techniques used in their production. In one branch of medallic work, namely, medals made as Service awards, which are produced in large numbers, the production methods approach those used for coinage. To many people a medal is an award—service or otherwise—and it is not generally appreciated that medals may be executed purely as works of art, such as is a picture, and that they may take on similar forms, although they are often associated with historical or commemorative subjects.

Mr. Sutherland then went on to point out the influence that technical production factors can have on the artists' inherent skill. There are two main divisions in production technique, namely, casting and striking. Many present-day medallic artists—in Italy and France especially—use the casting method. The artist models his design in wax or clay, putting into it everything he can by way of subtlety of detail, variation of surface texture, and height and variety of relief. From his completed model a mould is made, and from the mould the medal is cast direct. If the artist is not satisfied with the result, modifications can be made to the original model and the process repeated. It is claimed that cast metal "settles" with a sensitivity not found when metal is violently constricted in a coining press, and that as a result it holds both light and shadow with a gentleness of gradation and an absence of harsh contrast.

Unfortunately, only a few castings can be made from a given mould, so that the individual cost is comparatively high. For this reason the struck medal has its favourable features, and in Britain at least most contemporary medals are struck under pressure from dies. It is obvious that, in the case of medals required in large numbers, the striking process must be preferred. On the other hand, although many designs lend themselves to this technique, others equally certainly do not. The essence of a struck medal is the hardness or brightness of its surface, and a model which is full of tenderness, gentleness of texture and subtlety of light and shade is translated into a hard, bright and often unsuitable medal. Again, the adoption of a method in which metal is violently constricted and forced to conform to the pattern of a die imposes severe technical limitations on the artist himself. He must always consider to what extent he should provide for the pressure flow of metal in relation to the height of his relief, and the introduction of striking machinery has resulted generally in lowering of relief and regularising of design layout.

For well over 100 years, medallic art has had to face another mechanical device—the reducing machine—which has, in Dr. Sutherland's view, come too near to destroying, or at least diluting, the artist's personal touch, even in the case of medals well suited in design and character for die-striking, as opposed to casting. With the machine to rely on, an artist who wishes to make a design for a die-struck medal no longer needs to be an engraver of high skill, capable of cutting his design into hard metal dies, as was done for the innumerable coins made down to the 17th century. Instead he can work as a sculptor on a large-scale model from which he makes, first, a negative plaster mould. A positive plaster cast from the mould is metallised at its surface before putting on the reducing machine, which makes a positive metal replica of medal size. This, in turn, is used to punch the final negative die from which the positive medal is struck.

After six stages of processing in this way, it is not surprising that the characteristics of the artist's original model are weakened or impaired by the long and complex procedure. Moreover, the opinion has often been expressed that relief and detail which look well on an enlarged model, are not amenable when reduced by the machine by a factor of 4 or 5. In other words, neither modelling nor design can be truly translated on to a small scale, except by an intelligent hand. In these days of mechanisation and automation it is good to realise that there are spheres of human activity in which the hand, eye, mind and soul have still a part to play.

Birthday Honours List

Among those named in the Queen's Birthday Honours List were the following :—

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SIR GEORGE NELSON, Chairman and Managing Director, The English Electric Company, Ltd.

KNIGHTHOOD

A. W. GRANT, C.B.E., Chairman, Engineering and Allied Employers' West of England Association.

R. M. SHONE, C.B.E., Executive Member, Iron and Steel Board.

G.B.E.

SIR WILLIAM ROOTES, K.B.E., Chairman, Dollar Exports Council.

K.B.E.

A. FLECK, Chairman, Imperial Chemical Industries, Ltd.

C.B.E.

J. V. DUNWORTH, Head of Reactor Physics Division, Atomic Energy Research Establishment.

C. H. DUTTON, Vice-Chairman, Rotax, Ltd.

G. E. FOXWELL, Consulting Fuel Technologist.

C. A. F. HASTILOW, O.B.E., Chairman, Docker Brothers.

G. H. HOULDEN, M.B.E., Managing Director of the Shipbuilding Division, Vickers-Armstrongs, Ltd.

D. D. PRATT, O.B.E., Director, Chemical Research Laboratory, Department of Scientific and Industrial Research.

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H. P. R. SCOTT, Joint Managing Director, Summersons Foundries, Ltd.

H. E. STEEL, Chief Ship Surveyor, Ministry of Transport and Civil Aviation.

F. N. SUTHERLAND, General Manager, Marconi's Wireless Telegraph Company, Ltd.

R. E. SWIFT, Director of Aeronautical Inspection, Ministry of Supply.

H. G. TAYLOR, For services to the Chain and Chain Cable Industry.

J. N. TOOTHILL, General Manager, Ferranti, Ltd., Edinburgh.

P. B. WALKER Deputy Chief Scientific Officer, Royal Aircraft Establishment, Ministry of Supply.

O.B.E.

R. V. ATKINSON, Works Director, Gloster Aircraft Company, Ltd.

F. C. V. HOLMES, Chief Chemist, Cunard Group of Shipping Companies.

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R. A. WRIGHT, Works Manager, Skefko Ball Bearing Company, Ltd.

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W. S. BATES, Director and Secretary, Philip and Son, Ltd.

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F. W. BIRD, Laboratory Manager, Fullers Earth Union.

J. M. BOYD, Chief Switch Designer, Electric Construction Company, Ltd.

W. E. BRITTLE, Superintendent, Fulham Bulk Plant, Esso Petroleum Company, Ltd.

H. BROWN, Chief Engineer, Reads, Ltd.

H. BROWN, Engineering Chief Draughtsman, Harland and Wolff, Ltd., Belfast.

H. G. CHEEL, General Manager, General Electric Company, Ltd., Wembley.

F. W. CLARK, Brickworks Manager, Richard Thomas and Baldwins, Ltd., Belton and Crowle, Lincolnshire.

H. W. COX, Electrical Engineer, Electrical and Musical Industries Engineering Development, Ltd.

H. CRUMP, Works Manager, Engineering and Shell Division, Beans Industries, Ltd.

K. DAY, Leading Draughtsman, John I. Thornycroft, Ltd.

C. FOSTER, Mechanical Engineer, Power Samas Accounting Machines, Ltd.

J. W. E. GARDNER, Chief New Development and Process Engineer, D. Napier and Son, Ltd., Liverpool.

T. C. HAMILTON, Labour Officer, Imperial Chemical Industries, Ltd., Stevenston, Ayrshire.

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C. R. HINDS, Locomotive Works Manager, Darlington, North Eastern Region, British Railways.

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J. HUTTON, Fitting and Assembly Shop Superintendent, Albion Motors, Ltd.

R. W. LEWIS, Chief Chemist, Burndept, Ltd.

H. LLOYD, Director and Supervisory Export Manager, Marsh Brothers and Company, Ltd.

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G. REEVE, Area Organiser, United Patternmakers' Association.

F. S. SALTER, Chief Designer, Hydraulic Department, Loewy Engineering Company, Ltd.

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H. T. STEAD, Assistant Works Manager, Charles Roberts and Company, Ltd.

W. C. STYAN, Engineer-Designer, Vickers-Armstrongs, Ltd., Crayford.

G. H. TODD, Shipyard Manager, Hawthorn Leslie (Shipbuilders), Ltd.

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A. C. BAGNALL, Welfare Assistant, Steel, Peech and Tozer, United Steel Companies, Ltd.

Continued on page 35

Modern U.S. Gas Carburising and Carbonitriding Practice

By Norbert K. Koebel

Director of Research, Lindberg Engineering Company, Chicago, Illinois.

On a recent visit to this country, Mr. N. K. Koebel, Director of Research of the Lindberg Engineering Company, of Chicago, lectured to more than a hundred British engineers, drawn mainly from the automobile industry, on modern American gas carburising and carbonitriding practice. The meeting was arranged by Electric Resistance Furnace Co. Ltd., Lindberg's British associate.

THE advantages of gas carburising over the old method of pack carburising include: (*a*) lower cost; (*b*) control of carbon in the case; and (*c*) automation of equipment. Lower carburising costs are made possible by the fact that less time is required to heat the work alone, compared with the time required to heat the work plus the container and carburising compound. Besides the weight of the extra material to be heated, the carburising compound acts as a shield or insulator to prevent the work from absorbing heat quickly. From a cost point of view, carburising gas per pound of work treated is much cheaper than carburising compound. Perhaps the greatest saving results from reducing the amount of labour required for handling the carburising compound and work into and out of the containers. This is particularly so in America where labour costs are high.

From a metallurgical point of view, gas carburising makes it possible to control the carbon content of the case. This is not possible with pack carburising as the latter produces saturated austenite at the temperature of carburising; for example at 1,700° F. (925° C.) the percentage of carbon at the surface of the case would be approximately 1·25%. In America the trend now is to carburise to controlled carbon contents between 0·75% and 0·90%, in order to eliminate retained austenite from the hardened case, especially with alloy steels. Other aims are the prevention of the formation of a steep carbon gradient that may cause spalling, and the reduction of distortion. Generally speaking, controlling the carbon in the case between 0·75% and 0·90% has reduced rejects and failure of parts in service.

The fact that gas carburising lends itself to the design of automatic furnaces is another important reason for its use. The automation of equipment reduces labour, which, as pointed out above, is a big factor in costs in America. Furthermore, the automation of equipment creates better working conditions to satisfy labour. In America it is becoming exceedingly difficult to obtain labour for dirty, back breaking jobs, such as the handling in pack carburising. Furthermore, the automation of equipment reduces the human error and permits better quality control.

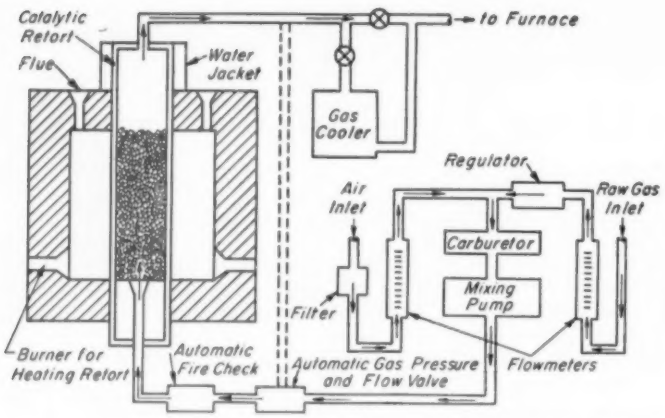
Early Gas Carburising Practice

Before considering modern gas carburising techniques, perhaps it will be best to discuss early practice. The first gas carburising furnaces were vertical retort batch furnaces, using a hydrocarbon fluid to generate the gas in the furnace. The hydrocarbon fluid was drip-fed into the furnace on to a hot alloy baffle, which caused the fluid to volatalise and react with the air in the furnace to produce a mixture of hydrogen, carbon monoxide, methane and nitrogen. With a tightly sealed retort it was possible to control the amount of fluid to generate a carburising gas. Later, such gases as natural gas or propane were also used in place of the fluid.

The early technique of gas carburising by fluid, or by straight natural or propane gases had several disadvantages. Controlling the amount of fluid to eliminate sooting was not always easy, and soot interferes with the reaction of nascent carbon with the steel surface. Nascent, atomic carbon is required for gas carburising, not molecular carbon, such as soot or coke. Thus, sooting or coking slows down the carburising process. Furthermore, soot and coke increase the cleaning costs of the parts, and excessive soot in the furnace increases the maintenance cost. The drip-feed hydrocarbon oil or straight natural gas process also made it difficult to control the content of the carbon in the case by the diffusion process, which will be explained later. Another reason why such methods have become out of date in America, is that they can be used only in tightly sealed retort batch type furnaces. On continuous furnaces, requiring a large volume of gas for purging, due to opening of doors during the carburising cycle, excessive soot would be formed if straight hydrocarbon oils or gases were used.

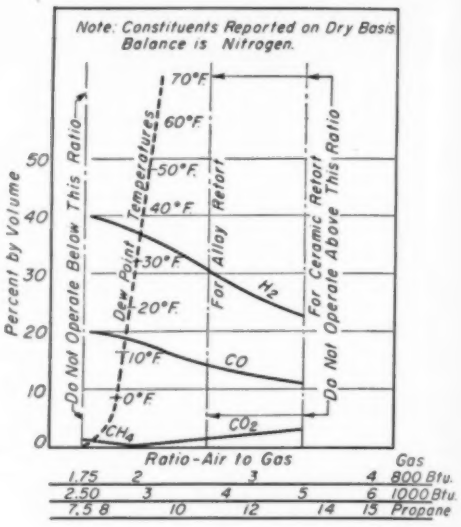
Modern Gas Carburising Practice

The modern gas carburising practice is to use a separate and controllable carrier gas enriched with a hydrocarbon gas to obtain fast carburising during the initial stages. A carrier gas is a hydrocarbon gas completely reacted with air, and consists of hydrogen, carbon monoxide, nitrogen, a small but controllable water vapour content, and a hydrocarbon content under 1%. The fact that the gas has a hydrocarbon content under 1% makes it a completely reacted gas. With such a gas, the water vapour content can be adjusted so that the gas is in equilibrium with any carbon-content steel, as will be shown and explained later. To attain fast carburising rates, however, it is desirable to have as high a carbon potential as possible, with a certain amount of a hydrocarbon gas such as methane to crack on the work to produce nascent or atomic carbon. To obtain a gas that will produce a saturated austenite on the surface, so as to provide a high carbon gradient for rapid diffusion and carburising, a small amount of



Courtesy of Metal Progress.

Fig. 1.—Schematic flow diagram of endothermic atmosphere generator.



Courtesy of Metal Progress.

Fig. 2.—Approximate analysis of endothermic generator gas when cracking various gas-air mixtures, the gases being natural gas of 800 or 1,000 B.t.u./cu.ft., or commercial propane.

hydrocarbon gas, such as natural gas, propane, or butane, is added to the carrier gas. The amount added depends on the total surface area of the work carburised, and not the weight of the charge. The surface area creates the demand for the carbon and thus the amount of hydrocarbon gas, which must be controlled to prevent sooting from taking place on the work. This is done by trial and error, or by instrumentation, which will be described later. During the last stages of the carburising cycle, the hydrocarbon gas is shut off and the carbon in the case is allowed to diffuse inwards and outwards to the atmosphere of the carrier gas, which is adjusted for the carbon content desired. By this method a controlled carbon in the case can be reproduced and work free from soot, in fact bright, can be obtained. In the case of continuous furnaces, carrier gas only is used in the diffusion zone to control the percentage of carbon in the case.

Principle of the Endothermic Generator for Producing the Carrier Gas

The endothermic (heat absorbing) type of atmosphere generator has been accepted by American industry as the most convenient and practical for preparing furnace atmospheres for carrier gas for carburising and carbonitriding and for the neutral hardening of medium, high-carbon and tool steels. In fact, the endothermic generator is the backbone of all controlled atmosphere heat treating, and, therefore, this process must be explained if one is to understand modern gas carburising and carbonitriding and related processes of neutral hardening. The primary reason that the endothermic generator is used throughout industry in America is that natural gas (90 to 95% methane), now available at a low cost throughout America, can easily be cracked to produce a consistent atmosphere to meet the requirements of neutral hardening, carbon correction, gas carburising, carbonitriding, and homogeneous carburising, without elaborate gas generating equipment requiring chemical purification and drying towers. The endothermic generator can be operated by any shop man, and the only instrument required to adjust the generator to ensure that it is in equilibrium with a steel of any carbon content is a simple dew-point meter, or an instrument for measuring moisture in the gas it produces.

This statement is made with confidence, since the research laboratory of the Lindbergh Engineering Company has completed a five-year study of equilibrium relationships between the dew-point of endothermic furnace atmospheres and straight carbon steels, low-alloy production steels, and tool steels.

Although it has been mentioned that natural gas is used in America, the endothermic generator will work equally well cracking propane, butane or any other hydrocarbon gas. Manufactured gas is suitable, but not as desirable as propane or butane, because it varies in chemical analysis and this creates a more difficult control problem in producing a furnace atmosphere with a definite carbon potential by the dew-point method. In Great Britain, manufactured gas or town's gas is used for cracking in the endothermic generator almost exclusively, without any great difficulty. If propane or butane is used, the raw gas must not contain more than 5% unsaturated hydrocarbon gases, such as propylene or butylene, as unsaturated hydrocarbons do not crack properly and soot the catalyst. If the above specifications are met, the endothermic generator will work equally as well in Europe as in America. In fact, some localities in America operate on propane or butane, and some operate on manufactured gas. Thus the statement which is often heard in Europe, that gas carburising is successful in America because of natural gas, is not correct. In America, natural gas is used where it is available because of its low cost, but this does not mean that where it is not available the benefits of gas carburising and heat treating by modern controlled atmospheres are not attainable.

In reference to the endothermic process as shown in Fig. 1, hydrocarbon gas and air are metered in such a proportion that there is just sufficient oxygen to form carbon monoxide and hydrogen, without any excess for carbon dioxide or water vapour. After the air-gas mixture is compressed to about 1 or 2 lb./sq. in. gauge,

Fig. 3.—Lindberg endothermic generator as used in America to-day.

the mixture is passed through a firecheck to the heated catalyst in a pressure-tight retort heated externally (usually by gas firing). The temperature of the catalyst is extremely important to obtain a gas completely reacted and of consistent analysis. A temperature of 2,000°–2,200° F. (1,095°–1,205° C.) in the heating chamber outside the retort results in a completely reacted and stable gas mixture.

After passage over the catalyst, the reaction is "frozen" by chilling the gases to 600° F. (315° C.) in a water jacket surrounding the top of the retort, thus preventing the reaction from reversing and forming carbon and carbon dioxide from carbon monoxide. (The reaction in that direction occurs in a temperature range from 1,300° F. (705° C.) downward to 900° F. (485° C.).) The soot-free reacted gas can be further cooled in the gas cooler for metering and distribution purposes if desired.

Considering natural gas to be composed chiefly of methane (CH_4) the overall chemical reaction taking place in the endothermic generator may be written :—

$$2CH_4+O_2+3{\cdot}8N_2 \longrightarrow 2CO+4H_2+3{\cdot}8N_2$$

This overall reaction is not endothermic, as the generator's name implies, but is actually, exothermic. The reaction takes place in two stages, however. In the first stage, some of the methane burns with the air and generates heat. In the second stage, the surplus methane reacts with the carbon dioxide and water vapour produced in the first stage, and this second reaction is definitely endothermic. Therefore, a high temperature and sufficient catalyst bed are required to obtain complete reaction, so that there is no carbon dioxide, excess methane or excess water vapour in the final atmosphere. A reversible reaction is then prevented by "freezing" the reaction as explained above.

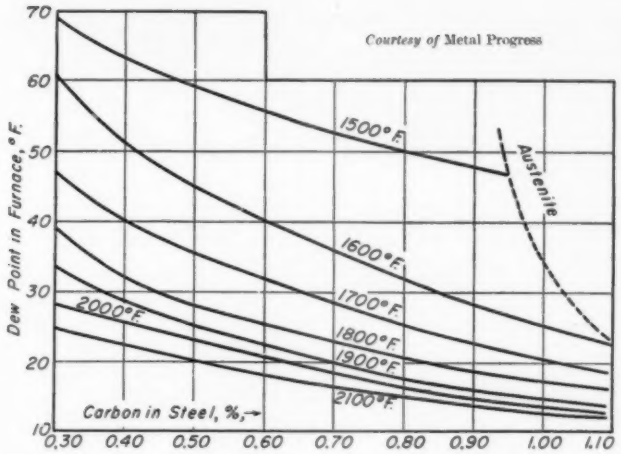


Fig. 4.—Equilibrium between straight carbon steels and dew-point of endothermic furnace atmospheres.

Fig. 2 shows that the air-gas ratio can be altered slightly to vary the dew-point (moisture content) of the gas without appreciably affecting the carbon dioxide or residual methane. Note that from a 35° F. dew-point down to 0° F. dew-point, there is no carbon dioxide in the atmosphere. The residual methane ranges from zero to approximately 1·5% if the generator is operating efficiently. If the dew-point is above 35° F., no methane will be present, but the carbon dioxide will steadily increase as more air is used in the air-gas ratio until, at a 70° F. dew-point, there will be about 1% carbon dioxide. Experience has proved that dew-points from 70° to 10° F. will be in equilibrium with steels containing from 0·20 to 2·0% carbon content. Fig. 3 shows a Lindberg endothermic generator as used in America to-day.

In order to obtain precise data for controlling the carbon potential of furnace atmosphere for carburising, carbonitriding, carbon correction, neutral hardening and furnace brazing at high temperatures, the Lindberg Engineering Company developed the set of equilibrium curves shown in Fig. 4 by a laborious method of exposing hundreds of samples of steel to a range of dew-points from 0° F. to 70° F. at heat treating temperatures of 1,400° F. (760° C.) to 2,100° F. (1,150° C.). This empirical development of curves was found necessary because the theoretically calculated curves did not agree with the results found in practice.

The method of applying the equilibrium curves to gas carburising is to adjust the dew-point of the endothermic generator gas to that shown on the curve for the carbon content desired at the carburising and diffusion cycle. At the beginning of the carburising cycle is added 8 to 10% natural gas, 3 to 5% propane, or 1 to 3% butane, depending on the surface area of the work to be treated. At the end of the cycle the hydrocarbon enrichment is shut off, and the carbon in the case allowed to diffuse inwards and outwards to obtain the carbon content shown on the equilibrium chart.

Equilibrium curves are also very useful for "homogeneous carburising," which may be defined as carburising a low-carbon steel throughout to a uniformly higher carbon. This process is used to advantage to

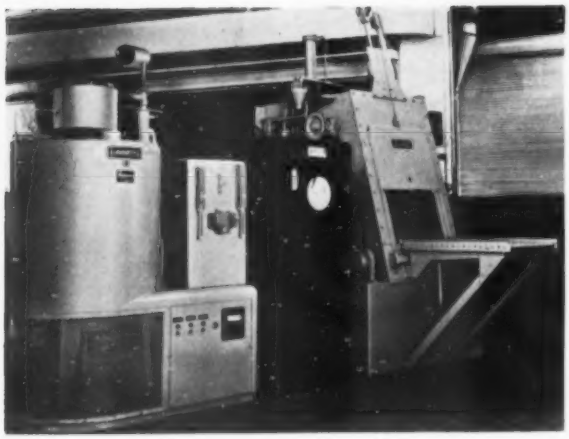


Fig. 5.—Lindberg 500 cu. ft./hr. Hyen generator, with Carbotrol unit and carbonitriding furnace.

carburise low-carbon steel stampings (up to $\frac{1}{16}$ in. thick) instead of working a 0·70% carbon annealed sheet. More complicated stampings with sharp bends can be formed without cracking, and, furthermore, the low-carbon steel is appreciably cheaper. The heat treating cycle is considerably longer but, on these stampings, the process is still more economical than using the higher carbon steel. There is considerable saving in tool life by blanking and forming low-carbon steel instead of high-carbon steel.

The endothermic atmosphere equilibrium curves are particularly useful in the carbon correction of steel. Aircraft specifications in America for such things as bolts require that any " mill bark " on the surface be recarburised to the content of the core. Bolts with rolled threads are one example where decarburisation is not removed in manufacture, and, inasmuch as low carbon on the surface of the thread lowers its fatigue properties, specifications for highly stressed bolts now call for carbon correction. To this end, all that is required is to allow the bolts to soak long enough at the hardening temperature with the dew-point in the furnace adjusted as shown on the equilibrium curve in Fig. 4 for the steel being treated.

For example, if an S.A.E. 4140 steel were being heat treated and simultaneously carbon corrected, a hardening temperature of 1,600° F. (870° C.) would be used, and Fig. 4 shows that a furnace dew-point of 52° F. would be in equilibrium with this steel. If the bolts were soaked long enough at 1,600° F., the carbon would be restored to 0·40% and there would be no danger of exceeding this amount, regardless of time at temperature. (Usually a soak about twice that required for normal hardening is required.)

The application of the equilibrium curves for endothermic furnace atmospheres for neutral hardening is quite obvious. All that is required is to adjust the endothermic generator and flow of atmosphere through the furnace so that the indicated dew-point temperature on Fig. 4 is maintained in the furnace chamber at the hardening temperature for the steel being treated. Lindberg Engineering Company has also developed a set of curves for the high alloy tool steels.

At the present time, in America, the majority of installations are controlled manually by the use of an Alnor indicating dew-point meter. This make of meter is very reliable for both low and high dew-points. The instrument is easy and foolproof to operate, and the results are reproducable by any shop man. Lindberg Engineering Company have just recently developed an automatic, controlling and recording dew-point device known as the Carbotrol, with which the operator can set the dew-point desired in the furnace, and the instrument will automatically control the furnace to that dew-point and, thus, to a definite carbon potential. This instrument, together with the Lindberg endothermic generator and a Lindberg automatic batch type carburising and carbonitriding furnace is shown in Fig. 5. Automatic control of carbon potential is being given a great deal of study and development in America, and within the next few years great strides should be made in this field.

In applying the equilibrium curves by either an indicating manually operated dew-pointer or by an automatic recording controller type such as the Lindberg Carbotrol, it is of utmost importance that the dew-point be taken from the furnace chamber and not from the generator. The sampling tube must be a high-alloy pipe or tube, preferably Inconel. Ordinary steel or low-alloy will oxidise and cause erroneous readings. If the sampling tube is to be a permanent one, the tube should extend well through the refractory wall, keeping the end as close as possible to the work ; the furnace door should never be left open while taking dew-points. The operator should make sure that abnormally high dew-points which occur on starting up equipment do not form condensate in the sampling tube.

The Modern Gas Carbonitriding Process

The carbonitriding process is a gaseous method of applying a carbon and nitrogen case, which was developed to replace the liquid cyanide method of case hardening. The same endothermic gas generator as described for gas carburising is used as the carrier gas in the carbonitriding process. The only difference between the gas carburising process and the carbonitriding process is that a third gas, anhydrous ammonia, is added to supply nascent nitrogen. Carbonitriding is generally carried out between 1,500° F. (815° C.) and 1,600° F. (870° C.), whereas the deeper case carburising is carried out between 1,600° F. (870° C.) and 1,750° F. (955° C.) to obtain faster diffusion. Carbonitriding is normally used for light and medium cases from 0·003 in. to 0·020 in.

A typical atmosphere for producing a carbonitrided case is one composed of an endothermic atmosphere containing 2–4% propane and 5–15% anhydrous ammonia. The percentages are based on the amount of endothermic carrier gas used in the furnace. The dew-point of the gas in the furnace should be adjusted between 30° and 40° F. for the best results. The exact percentage of enriching gas and ammonia varies with the temperature used and the characteristics of the case desired. The character of the case can also be controlled by the temperature. The lower the carbonitriding temperature, the greater will be the nitrogen in the case, and thus the greater will be the hardenability of the steel treated. The higher the temperature the greater will be the carbon in the case. This will hold true without changing the gas composition. As stated above, the degree of nitrogen and carbon can also be varied by changing the composition of the gas, by varying the

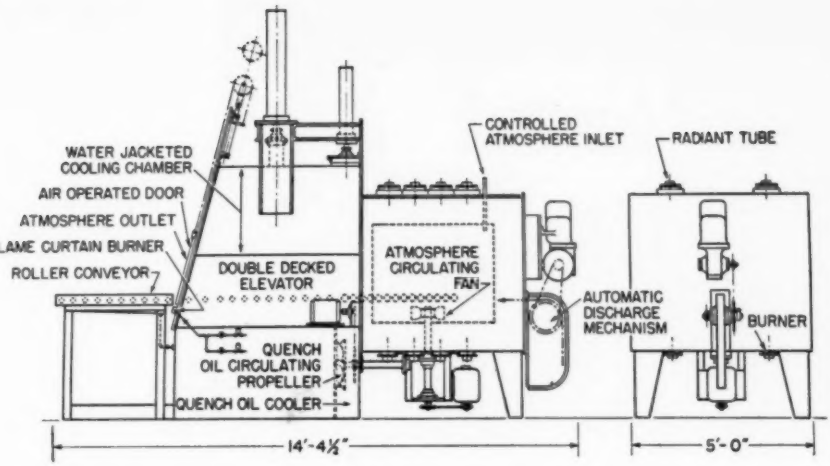


Fig. 6.—Cross-section of Efco - Lindberg batch type carbonitriding furnace.

hydrocarbon enriching gas, the ammonia and the dew-point of the endothermic carrier gas. Thus the process has considerable flexibility.

There are so many advantages of the carbonitriding process over liquid cyaniding that the latter has become obsolete in America to-day. The chief advantages may be listed as follows: (*a*) lower cost of operation; (*b*) elimination of dangerous cyanide furnaces; (*c*) elimination of cyanide disposal problems; (*d*) elimination of washing cyanide from work; (*e*) creation of healthier and better working conditions; (*f*) lower labour cost for operation; (*g*) control of type of case; (*h*) easier automation of equipment; and (*j*) use of cheap free machining steels in place of the more expensive alloy carburising steels.

The carbonitriding process lowers the cost of operation over salt cyanide because the average cost for the drag-out of cyanide per pound of work treated is five cents, whereas the cost of atmosphere for carbonitriding is a fraction of a cent. Furthermore, salt baths have a high radiation loss, whereas the carbonitriding furnaces are well insulated, and most of the heat energy goes into the work being treated. Salt baths also have a higher maintenance cost than furnaces. Considerably more labour must be used to operate cyanide baths because of handling the work in and out of the salt, and stringing the work for heating and quenching. In the carbonitriding method, the work can be random-loaded into baskets up to 300–400 lb., and batch quenched without coming into contact with the air. The furnace is mechanised in that the operator does not have to handle the work during the quench. The work comes from a carbonitriding furnace bright and free from salt, thus eliminating a washing problem which can become troublesome if parts have blind holes. If the carbonitrided work is not to be plated, the oil film can be left on for corrosion protection, and the parts can go directly into production. If the parts are to be plated, the oil film can easily be washed off, and the parts can go directly into the plating baths. There again money is saved in handling, and also in extra cleaning operations.

Another great saving and the elimination of a very difficult and troublesome problem is that of cyanide disposal. All localities in America prohibit the dumping of cyanide salts or wash water from cyanide into sewers and streams. This means that either a costly method of neutralising the cyanide waste by a chemical means is employed, or the cyanide is disposed of by an equally costly method of burying it in a deep hole. Along with the cyanide disposal problem every manufacturer wishes to do away with the poisonous cyanide and the unhealthy working conditions around a cyanide salt bath. Labour is becoming more difficult to obtain and please, and if something were not done about cyanide salt baths there would be few operators left in America to man them. In conjunction with the demand, the carbonitriding furnace is easy to make automatic in operation.

Apart from the foregoing savings and advantages, the carbonitriding furnace lends itself to better metallurgical control. The character of the case can be varied to suit the application as described above. Cyanide produces a steep gradient, and, where a grinding operation is to be performed, the high hardness and wear resistance is lost if only a few thousandths are removed from the surface. The carbonitriding process produces a gradual gradient with high hardness well below the surface, so that a grinding operation does not remove the hardness or wear resistance. Furthermore, the elimination of the salt film, which acts as insulation, permits carbonitrided work to be oil quenched, and eliminates water quenching. This prevents warping and gives much better control over distortion and change in dimensions. The elimination of the salt also permits batch quenching, which has already been described in terms of savings on labour for handling work. Furthermore, the high hardenability produced by adding nitrogen to the steel permits one to select a cheap free-machining steel rather than a more expensive alloy steel, and a steel that is more costly to machine.

The cross section of a modern batch type carbonitriding furnace made by Lindberg and EFCO is shown in Fig. 6. This furnace can be made completely automatic. All that the operator has to do is to place a charge into the purging vestibule, which is also the quench chamber of the furnace. When the door closes a timer will allow the load to be purged free of air in the protective atmosphere. The load will then be automatically charged into the furnace. At the end of the proper cycle set by a timer, the load will be automatically pushed from the furnace chamber on to the elevator for quenching. The load is quenched automatically, and at the end of the quench cycle a signal is flashed as an

Fig. 7.—Efco-Lindberg GVRT.243615 carbonitriding furnace.

indication to the operator to remove the load and charge a new one. Note that the furnace has an upper atmosphere quench chamber for use in annealing or slow cooling the charge when desired. Thus the furnace can be used for carbonitriding, carburising, annealing or neutral hardening, by merely adjusting the furnace atmosphere for the process desired. The quench system has its own automatic cooler and a powerful oil agitator for batch quenching. Heaters can also be placed in the oil quench for martempering between 350° F. (175° C.) and 450° F. (230° C.) to reduce distortion. This method is being used to great advantage in America ; a special high temperature mar-quench oil being used for the process. Fig. 7 shows an Efco-Lindberg carbonitriding furnace now being very successfully used in America and this country.

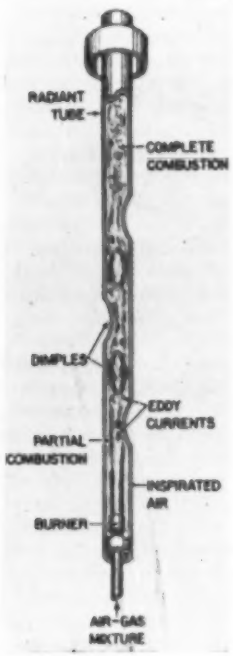


Fig. 8.—Efco-Lindberg straight radiant tube.

Design of Modern Gas Carburising and Carbonitriding Furnaces

Practically all the latest gas carburising and carbonitriding furnaces in America are designed for radiant tube gas firing. There are several reasons why gas is preferred to electricity. In the first place, gas is cheaper and is available almost everywhere in America. Natural gas pipelines now extend to almost every corner in the United States, and are being installed throughout Canada. The use of a gas-fired radiant tube promotes better efficiency than muffle furnaces of either the gas or electric type. Large muffles are costly, and the maintenance is greater than that of radiant tubes. To date, electric radiant tubes have not been too successful, the reason being that it is difficult to release the electric energy through an alloy surrounding tube without

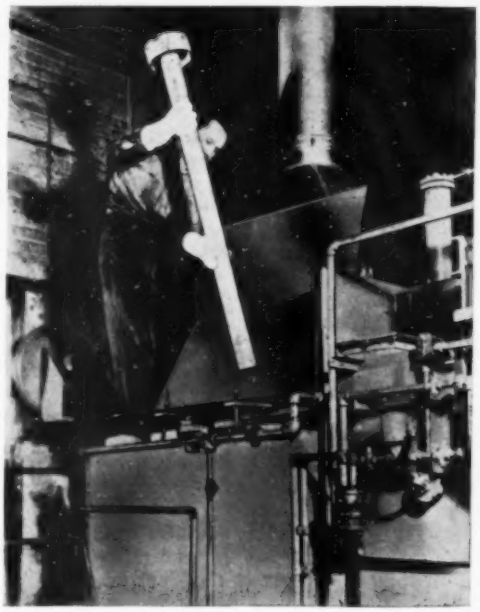


Fig. 9.—Removing Efco-Lindberg radiant tube whilst furnace is still hot.

burning out the electric resistor due to overheating. If the watts density is kept very low to overcome this problem, the radiant tube becomes very large for a small amount of input. Therefore, the furnace chamber must be made larger and the initial cost greatly exceeds that of the gas-fired radiant tube. However, Lindberg Engineering Company is now doing a great deal of research and development work on an economical electric radiant tube for localities in Europe which do not have gas.

The latest development in gas-fired radiant tubes is the Lindberg vertical type shown in Fig. 8. This is a seamless wrought Inconel tube with special " dimples " to cause turbulence to assist mixing of the gases, and a wiping action on the walls of the tube for efficiency. Since the tube is made of a good heat resisting alloy, long life can be obtained at high temperatures of 1,750° F. (955° C.) for carburising, and the tube can be operated intermittently at 1,850° F. (1,010° C.) for stainless steels and high carbon-high chromium tool

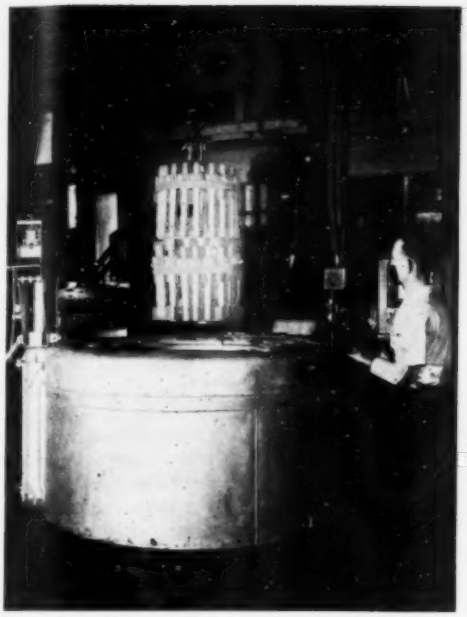


Fig. 10.—Efco vertical batch type gas-fired radiant tube furnace 2ft. 6in. diameter × 3 ft. 6 in. deep, for gas carburising automobile gears and similar parts to case depths of 0.065-0.085 in.

Fig. 11.—Efco continuous three-track pusher type furnace for gas carburising automobile transmission components to a case depth of 0·030-0·040 in. The furnace is heated by 100 Efco-Lindberg vertical radiant tubes, and the output is 530 lb./hr.

steels. One of the big problems with gas-fired radiant tubes of the U-bend or hairpin horizontal type was that the tubes usually burnt out at the bend. Another fault was that the bends were welded in and the carburising gases attacked the welds and caused leaks. Still another disadvantage of the hairpin horizontal type was that the tubes and bends were of a lower alloy cast material. Most castings are porous, and the carburising gases would deposit carbon in the pores and cause failure of the tube. Moreover, carbon or soot would deposit on top of the tubes and cause hot spots which resulted in excessive heating and failure. Another problem was that the horizontal tubes were bulky and difficult to instal, requiring the furnace to be shut down and cooled. The Lindberg vertical radiant tube only weighs 28 lb. and can be installed very easily while the furnace is hot, by slipping the tube out of a packing gland at the bottom of the furnace and out of a sand seal on top of the furnace—this can be done while the furnace is hot, in a matter of a few minutes, as shown in Fig. 9.

Experience in America has proved the life of the older designed horizontal hairpin type of tube to be approximately 8 months at a carburising temperature of 1,700° F. (925° C.). To date, after three years of operating the new Lindberg vertical radiant tube, reports show that the average life has been increased to 16–20 months at the same operating temperature. Some furnaces are operating with the original tubes, now over three years old. The Lindberg vertical radiant tube is perhaps the greatest single furnace development for economy in furnace history. Of course, along with the tube, the proper burners and combustion equipment were developed to obtain combustion efficiency in a relatively short tube. Furnaces operating in England built by Electric Resistance Furnace Company, work equally efficiently on manufactured gas as furnaces built by Lindberg operating on natural gas in America.

Figs. 10–12 illustrate three types of modern gas carburising and carbonitriding furnaces employing the Lindberg vertical radiant tube design.

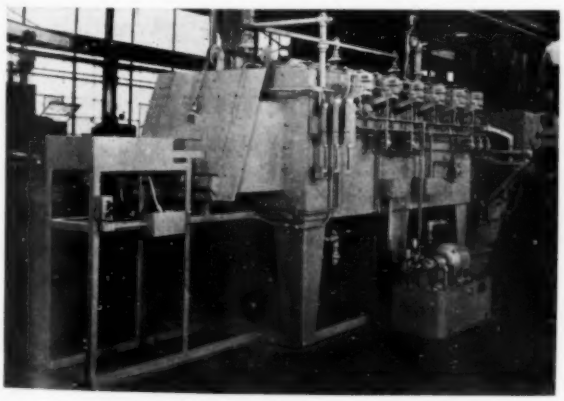


Fig. 12.—Lindberg single-track pusher type furnace for neutral hardening, gas carburising, and carbonitriding. It will accommodate trays 18 in. wide × 6 in. high over a heated length of 10 ft. The work is quenched directly from the tray and the maximum outputs are as follows: neutral hardening—550 lb./hr.; flash case carbonitriding (0·003-0·005 in.)—475 lb./hr.; medium case carburising (0·030-0·040 in.)—240 lb./hr.; and heavy case carburising (0·050-0·060 in.)—130 lb./hr.

Land London Office

LAND PYROMETERS, LTD., of Sheffield, announce the opening of a branch office in London on the 1st of July, 1955, at 227, Holland Park Avenue, Shepherds Bush, W.11 (Telephone Park 3633) At the same time, Mr. I. H. Gordon, who has for many years been associated with industrial instruments, is joining Land Pyrometers as Southern Area Manager.

Metallurgy as a Separate Science

Presidential Address to the Institution of Metallurgists

At the Annual General Meeting of the Institution of Metallurgists, held in London on May 25th, Professor F. C. Thompson took over the office of President from Mr. W. Barr. In the first part of his Presidential Address, of which an account is presented here, Professor Thompson discussed the justifications for regarding metallurgy as a distinct branch of science in its own right, together with the qualities to which members, as metallurgists ought to aspire.

IT would be idle to deny that in some measure the facts, the theories and the techniques of chemical and physical science are the tools with which the metallurgist works. This, of course, is true of all sciences, and more and more so as their frontiers are disappearing. It is important for us, therefore, to enquire what metallurgy really is, and what are the justifications for considering it a distinct branch of science in its own right.

Material Justification

There is first, of course, the purely material justification: the provision for the use of other sciences and technologies of the materials on which to some extent their very existence depends; the autoclave for the chemist, the drill for the geologist and mining engineer, or magnetic materials for the electrical engineer and the physicist. Without these, workers in such fields could not carry on. This aspect of our consideration extends, however, far beyond such limits, since the engineer, and through him the whole of our civilisation in which modern science can alone exist, requires more, new, and better materials for the very possibility of progress. It has become almost a platitude to say that the whole history of civilisation is the history of man's knowledge of, and mastery over, the metallic elements, but this *is* a fact which has been true in the past, and was never more so than to-day. A field of knowledge and human activity of such universal importance, and of such significance in other aspects of scientific work, is surely worthy of recognition both in the social as well as in the purely scientific fields.

This, though going far towards it, does not perhaps completely justify the separation of metallurgy—the whole field of study of the metallic elements—from that of other concerns of inorganic chemistry, and its place as a separate and distinct entity in the scientific cosmos. Why, in other words, does metallurgy justify an individual status as an independent scientific discipline?

Those who know most about the content of the field of metallurgy have the least qualms regarding this separation, but perhaps Professor Masing's apologia[1] comes as near as any to defining its real province: "Between metallurgy and chemistry there exists a most significant distinction. The unit with which the chemist works is the *atom*, and his primary interest is the molecule of the compound. His concern is with the reactions between molecules as they are presented to us in the chemical equation... Metallurgy on the other hand is the study of *aggregates* of atoms, how they exist in the solid, and, to a less extent, in the liquid states... Metallurgy, then, is the study of metallic *substances*, whilst the atom, as such, is of subsidiary interest."

Those of our members who are concerned with the metallurgical aspects of nuclear energy, might perhaps disagree with the last half of the final sentence, but as a broad description of our interests it may suffice.

Although, then, the boundary may not always be sharply defined, the scientific field of the metallurgist is sufficiently clearly outlined for the subject to be legitimately considered as a specific and distinct branch of knowledge.

Contribution to General Scientific Knowledge

If it be true that a Church can survive only through its missionary zeal, so it seems to me that for a science to justify a separate existence as such, it must make its own contribution to the general pool of scientific fact and hypothesis. To what extent can this be claimed for our own?

That the metallographer has made a most important contribution to our knowledge of the solid, i.e., the crystalline, state, there can be no reasonable doubt. The field of rheology, for instance, has been immensely enriched by studies of the deformation and flow of the metals; and the similarities for instance between these and the deformation of synthetic fibres, although there are most important differences, are still quite striking.

How much modern engineering progress owes to work in metallurgical laboratories, and the extent to which further advances are awaiting new alloys for their exploitation, are sufficiently well known to need no emphasis here. In the field of nuclear engineering, the responsibility of the metallurgist—in part one of a rather new type—both for the speed and the success with which the new possibilities are rendered available to human needs requires no embroidering. If the range of materials now available to the engineer be compared with those at his disposal fifty years or so ago, the contribution of our science to the material as well as to the scientific progress of mankind will be appreciated. On the one hand, the plain-carbon steels together with a very limited range of alloy tool steels, wrought iron, the ordinary cast irons, brass and bronze; on the other, the high-speed steels, the "modified" and age-hardening alloys of aluminium, almost the whole range of alloy constructional steels, nodular cast iron, the magnesium alloys, the whole range of stainless and corrosion resistant steels, magnetic materials of enormously increased coercive force or permeability, free-cutting steels, and so on. This is progress of which any science or technology may be proud, and these advances have been made side by side

with corresponding advances in the fundamental knowledge of our materials which provide justification for the belief that future progress will be neither slower nor less spectacular.

The petrologist can give, and has given, first-rate help in the study of ores, slags and refractory materials, whilst the metallurgist's study of the constitution of slags and their reactions may well provide the key to certain problems of the geologist's magmas.

The importance of the stainless steels and still newer materials, such as tantalum and more recently zirconium, to the surgeon, and the highly specialised range of alloys now at the disposal of, or under investigation by, the dental profession, illustrate the assistance which has, and is being given in a sphere of activity of most direct importance to human welfare. In the treatment of certain types of malignant disease, the γ-radiation, for which Gold 198 is an obvious source, is required. Along with γ-radiation this gold, however, emits the β-form, which must be filtered out to avoid severe local damage to the tissues. It is to the metallurgist that the solution of this problem is due, by coating the seeds of gold with a platinum sheath sufficiently thick to absorb the β-radiation emitted after irradiation of gold with neutrons.

In relation to the chemical sciences, the outstanding contribution which the metallurgist has made ; at any rate on the more technological side, has been the discovery of the corrosion resisting alloys, and the explanation and, therefore, the elimination, of the serious defects from which the earlier steels suffered. I well remember the first stainless steel pocket-knife shown me by Professor Aitchison in, I believe, 1913, but who could at that time have envisaged the revolutionary changes in chemical engineering of which the newborn steel was the harbinger ?

The great advances in inorganic chemistry in recent times, and its " new look ", are in no small measure concerned with the metals, and to this the metallographer has contributed to no insignificant degree. The work of Hume-Rothery and his school is now part of the very bricks and mortar of which this structure is built. No better example is known of the dependence of atomic size on the co-ordination number than that provided by the allotropes of iron, whilst in a book such as Darken and Gurry's "Physical Chemistry of Metals" we have a first-rate treatment of that branch of science, but approached directly from the viewpoint of the metallurgist, both industrial and theoretical.

One could go on multiplying such examples almost indefinitely, but enough has been said to show that whatever assistance metallurgy has received from the other sciences, it has returned this help in full measure. Metallurgy, then, may be compared with a man who does a full day's work, who pays his debts as he goes along, who is not above accepting help from his neighbours, but who is meticulous, as opportunity offers, in returning such good offices—perhaps with a bit of interest. In other words, an independent and self-respecting member of his community. A typical north-countryman !

Professional Qualities

That, then, as I see it, is the subject, at once both technology and science, which this Institution exists to foster. What now are the qualities to which we as metallurgists ought to aspire ?

In 1640 the first book on American metallurgy was published in Madrid.[2] The author, Barba, a Roman Catholic priest stationed at Potosi in Bolivia, discusses' and obviously from first-hand experience, the whole field of metallurgy of that region. Although the book is said to have been banned and burnt by the Inquisition, three copies are stated by the translators to be known, all in the British Museum. In one chapter, " *Which Treats of what the Metallurgist should be, and what He must Know* ", Barba says :

" Most weighty is the Confidence placed in the Metallurgists, because all the Riches produced by this most prosperous Land are entrusted to them, without reckoning or Account of what part thereof they are bound to return. Their Reputation is the only assurance of their Truth-telling as to what the ores have yielded. There is neither dispute over their sentence nor appeal from it ; which is the strongest of Reasons why the urge of their own Interests may incite them to take of the yield unto themselves. Much need of a Christian Honour have they who enjoy these endless Opportunities, having, as the saying goes, ' their hands always in the Dough ', lest some of it stick. With much caution should one look upon him who he would charge with the task of treating his Ores, because there is no bad Substance which might hinder recovery, nor any consumption or loss of Quicksilver (both frequent and sure causes of Loss) which can cause such loss as a Metallurgist with a bad Conscience.

"Nor is it alone sufficient that his good Habits be examined and approved, if there is lacking the necessary Knowledge of the Art which he must exercise. He must be able to recognise the Ores, their qualities and differences ; to determine which are most fitted for Amalgamation and which for Smelting, or if there should be a combination of the Processes. He should know the harmful Substances which accompany ores, and not be ignorant of the way to remove them. He should know the Accidents which may happen to Quicksilver, and the ordinary way of milling on a small scale. And, in all cases he only can be considered as a treater of Ores, who knows at least how to make a small-scale Fire-assay of finely crushed Ore before amalgamating, in order to determine the Silver contained, and to know of a certainty and not through guesswork what he should recover. No Diligence should be omitted to secure this result."

Summarised in modern terms, the metallurgist should be an honest man, of wide experience, who *does* know his job. Though Barba wrote nearly three and a quarter centuries ago, could a better specification for any professional man be drawn up even to-day ?

Barba, though he could never have envisaged an Institution such as our own, would have welcomed it wholeheartedly. " The treatment of ores ", he says, " should not be practised except by him who understands it, and after Examinations and License of the Authorities." Examinations then are not new things, nor are the practical or oral tests to which he probably refers.

I have spoken of Barba's book at some length, but to Mr. Barr and our other members from north of the Tweed, his complete reliability is vouched for by his statement that (p. 50) " It is a well-known fact that in Scotland, out of pieces of the Beams of Ships, and out of Fruit fallen into the Sea, Ducks are produced."

Agricola, too, discussed the qualifications, both moral and professional, of the miner (in whom both the mining engineer and the metallurgist were then combined) in essentially similar terms, and stressed his importance to the community at large. Lest, however, it should be thought that these were the ideas of medievalists, and

that times have now changed so radically that they are no longer applicable, may I cite some remarks of the late Lord Horne quoted by Dr. Maurice Cook.

"There are", he said, "in my conviction, no workers in any realm of knowledge more capable of adding to the strength and prosperity of the Confederation of British Nations than those who give their time and thought to the development of our mineral resources and the production of our metals."

1 "Grundlagen der Metallkunde", 3rd Edition, 1951, p.1.
2 "El Arte de los Metales" Alvaro Alonzo Barba, Madrid, 1640. Translated by Ross E. Douglass and E. P. Mathewson. John Wiley and Sons, New York, 1923.

Plastics in the Foundry

One of the papers read at the Convention organised in conjunction with the British Plastics Exhibition, held in London at the beginning of June, dealt with recent developments in the use of plastics in the foundry. It was prepared by the Technical Sales Manager of Leicester, Lovell & Co., Ltd., and a summary is presented here.

In the use of synthetic resins to bond sand for making solid foundry cores, new developments are to be found mainly in refinements of the resins, and in methods of securing rapid cure, thus taking full advantage of the intrinsic properties of these thermosetting materials. Techniques used include high frequency heating and, more recently, blowing of resin-sand mixture into a heated corebox. The rheology of resin-bonded sands has been investigated and the results obtained should assist in overcoming core-blowing problems.

Hollow-shell cores with many advantages over solid cores are coming into prominence as an offshoot of the shell-moulding process, being made possible by the advent of non-segregating (pre-coated) resin-bonded sand. Various methods and specialised equipment have been developed for making shell cores, using simple dump/shake-out, blow/suck or limited-blow techniques. Economies are obtained in material costs, production time and fettling costs (through improved casting finish), consequently, a rapid extension of shell core production is envisaged. Resins used for this purpose are almost entirely of the phenolic type, but include both resoles and novolacs with hexamine.

The use of such resins in pre-coating sand for shell moulding has received much attention. Several methods of pre-coating sand have been proposed but only the F.E.L.L. process has been used on any substantial scale in Britain. Advantages of pre-coated sand for use in making shell moulds, in addition to the obvious absence of segregation which the term "pre-coated" implies, are discussed in relation to alternative shell moulding materials. The rapid development of shell moulding in British foundries during the last year or two is attributed to the availability of automatic or semi-automatic shell moulding machines, a clarification of the patent position, and the wide dissemination of knowledge and experience through the foundry industry—a process in which the plastics industry has played an important part.

The translation of shell moulding from semi-laboratory development work to full-scale production has brought into focus problems which were previously unrecognized except perhaps in the U.S.A. where the process came earlier into large-scale use. Minor differences between grades of resin are becoming significant through their influence on such production variables as investment and curing cycles. Health problems associated with dust from the fine silica sand, and to a lesser extent the powdered resin, claim serious attention, and point to the substitution of the apparently innocuous pre-coated sand wherever possible. The need for recovery and re-use of shell-moulding sand has become apparent in consequence of the limited availability of new sand in the quality required. More rapid and flexible methods of securing half-moulds are needed to meet varying production conditions.

Among the smaller applications of plastics in foundry work is the use of thermosetting resins for improving the surface of conventional "green-sand" moulds and so obtaining better casting finish. Furane resins have been found surprisingly inferior to phenolics for this purpose, but their outstanding heat resistance has been put to good use in making cheap core carriers for moderate runs. The possibility of casting patterns in furane resin compositions is being explored with a view to their use in place of metal patterns for shell moulding on short runs. For patterns and coreboxes used cold, cast epoxide resins hold great promise and are being actively investigated.

British Driver-Harris Progress

The Annual General Meeting of British Driver-Harris Co. Ltd., manufacturers of electrical resistance materials, was held on 24th May, 1955 at the Company's Works, and was followed by a luncheon at Alma Lodge, Hazel Grove, attended, at the invitation of the Board, by senior members of the Company's staff.

The keynote of the speeches was the tremendous progress made by the Company during the past five years. The Managing Director, Mr. R. M. Parry, referred to the continuing and increasing demand for nickel-containing alloys, particularly for the well-known Nichrome V and Nichrome alloys. This demand was not only the result of the high level of production in industry, but also of the widening field of application for these materials. Mr. Parry reviewed the steps taken to meet this demand, which included the setting up of a new laboratory, extensions to the factories and the addition of new plant at the Cheadle Works. This programme of expansion will not only speed up present production, but will also give the increased capacity which will be necesssary when supplies of nickel become easier.

Mr. F. L. Driver and Mr. S. M. Tracy, on a brief visit from America, both spoke of the extent of the Driver-Harris Organisation and of the active collaboration and exchange of technical information which takes place. Although manufacturing plants work independently in many countries, there is continuous and close co-operation between the companies which is a firm foundation for further progress and expansion in the future.

Wickman Ltd., have acquired all the issued ordinary capital of Arthur Scrivener, Ltd., Machine Tool Manufacturers, Tyburn Road, Birmingham.

Aluminium Centenary Exhibition

Interesting Display at the Royal Festival Hall

The widespread use of aluminium to-day tends to blind one to the fact that it is only a hundred years since the first piece of aluminium was produced in this country. The remarkable progress it has made—world output is doubling every ten years—was clearly illustrated by the exhibits at the Aluminium Centenary Exhibition held in London at the beginning of June.

ALTHOUGH it is 130 years since the Danish chemist, Hans Christian Oersted, first isolated aluminium, it was not until 1855 that a sample was prepared in this country. Two students of the famous Dr. John Percy at the then School of Mines in Jermyn Street, named Allan Dick and Richard Smith, made this metal by the chemical process developed by Deville in France, and Michael Faraday showed their product to those present at an evening discourse at the Royal Institution in March, 1855. Thus aluminium may be said to have attained its centenary in Britain this year, and the event has been celebrated by a Centenary Exhibition organised by the Aluminium Development Association. The Exhibition was open from June 1st to 10th and was honoured by a visit from H.R.H. The Duke of Edinburgh on Friday, June 3rd.

The Royal Festival Hall on the South Bank of the Thames proved to be a most suitable and tasteful venue, and both the foyer of the Hall and the immediate surroundings outside were fully used, the total number of exhibits being well over a thousand. As the President of the Association, Dr. Horace Clarke, said in his address to representatives attending the Press Preview, the purpose of the Exhibition was to show to the world some of the many ways in which aluminium is used, and the part which British industry has played in its development. Although this general theme was adhered to throughout the Exhibition, and relatively little space was devoted to the semi-fabricated products of the aluminium industry itself, the first display encountered by the visitor on approaching the hall showed the stages involved in changing bauxite into sheet, sections, wire and all the other raw materials of the engineer and manufacturer.

Bauxite to Semi-Fabricated Product

Four tons of bauxite, two of alumina and one of pure aluminium ingot illustrated the extraction process, together with symbolical representations of the equipment used, whilst an assortment of aluminium scrap, and examples of casting alloy ingots, showed how the recovery of alloys from scrap makes a large contribution to the raw materials of the industry in this country.

A large rolling slab, weighing nearly 3 tons, was followed by a rolled plate 30 ft. × 6 ft., weighing 1,300 lb., and a coiled sheet 670 ft. long × 50 in. wide, weighing nearly 6,000 lb., and produced by hot rolling. An extrusion billet 9 ft. long × 20 in. diameter was also shown, together with nine large extruded sections in lengths up to 50 ft. and weighing up to 25 lb./ft. The versatility of the extrusion method was demonstrated by several dozen short lengths of extruded profiles of widely varying shape and size, including hollow extrusions.

Drawn tubes were exemplified by a dozen samples ranging in diameter from ½ in. to 14 in., with varying wall thicknesses, and wire in round and shaped sections up to ½ in. was represented by four coils. A large aircraft under-carriage part in the roughly forged state, which weighed over 300 lb., and two large sand castings, a tyre mould weighing 600 lb. and a winchgear case weighing 260 lb., completed the display.

Historical

Turning to the sections of the Exhibition which were partly or mainly inside the Hall, the first to be considered is obviously that devoted to the history of the metal. Photographs of the pioneers of aluminium, from Oersted to Wilm, were shown, and historic exhibits included Dick and Smith's sample of metal, and a bar of aluminium presented to Michael Faraday by order of Napolean III. Early applications were exemplified by cooking vessels, a gilded eagle of the French army dating from 1861, and the statuette " La Diane de Gabies," a one-third size reproduction in aluminium of the famous statue in the Louvre. This was cast in Deville's aluminium about 1860, and is now in the possession of the A.D.A. Many interesting manuscript and printed documents recalled the early development of the Hall-Héroult extraction process and its industrial application in this country.

Properties of Aluminium

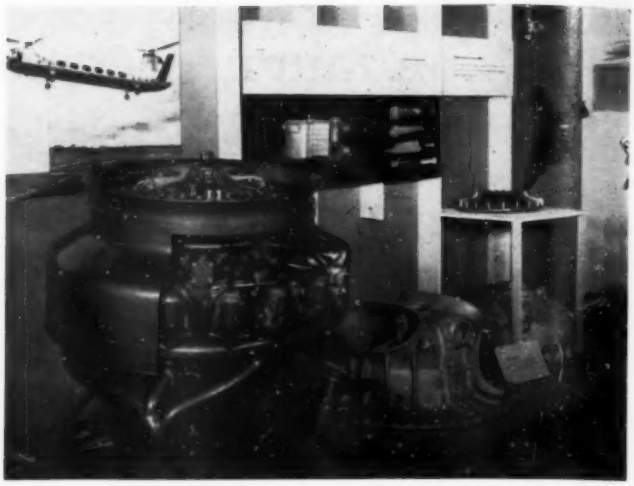
This section set out to illustrate, pictorially and by specimens, the six principal advantages of aluminium and its alloys, this theme being continued in the applications sections.

Lightness.—Indicative of the lightness of aluminium were photographs showing a long roof truss being carried by one man, and a climber on Mount Everest with a typical oxygen bottle made in alloy HE15-WP and weighing 9 lb. A series of 1½ in. diameter cylinders, each weighing 1 lb. allowed comparison of its specific gravity with that of other metals: the aluminium cylinder was 8 in. high, the steel cylinder 2·8 in., the zinc cylinder 3·1 in., and the copper cylinder 2·5 in.

Strength.—Alloying of aluminium with other metals results in considerably increased strength, as was emphasised by the high strength aluminium alloy test-piece displayed, which fractured at a load of 32 tons/sq. in.

Permanence.—The ability of aluminium to withstand the ravages of time was indicated by exhibits which included a photograph of the statue of Eros, a piece of

Part of aircraft section showing old and modern aluminium alloy propellers, an assortment of heat exchangers, and a pilot's ejector seat



Another display of aircraft components, including a power plant for a helicopter, and various castings and forgings.

roof sheeting installed on the church of San Gioacchino in Rome in 1897 and examined in 1949, and a saucepan which has had a service life of 61 years.

Good Finish.—Panels showed examples of etched, sanded, chemically brightened, polished and anodised, and electro-brightened aluminium, together with a few beautiful anodised and dyed articles.

High Conductivity.—To illustrate the high conductivity of aluminium, an aluminium bus-bar was shown together with a copper one of the same current-carrying capacity.

Non-Toxicity.—This was illustrated by aluminium containers for drugs and other pharmaceutical preparations.

Also in this section the difficult task was attempted of indicating by small samples how aluminium and its alloys may be readily forged, welded, heat-treated, manipulated, machined and pressed, and even the uninitiated could gain some impression of what the designer intended to convey.

The largest group of exhibits was that devoted to applications, divided into 12 sections.

Aircraft

Following the first recorded use of aluminium in the air in 1887, development has been continuous. The earliest all-aluminium aircraft in Britain was the Silver Streak, built by Short Bros. and Harland in 1920. A model of this aircraft was shown, together with others of modern aircraft, including the Gloster Javelin, Hawker Hunter, Folland Gnat, Vickers Viscount, Hawker Sea Hawk and Gloster Meteor.

A Hawker Heron propeller, forged in 1925 from a cast billet, could be compared with a modern Hawker Sea Fury propeller blade, machined from a forging to close balance tolerances, anodised and dyed black. Other forgings displayed included blades used in axial flow engine compressors, and impeller blades for the Dart and Nene Rolls-Royce aircraft engines, finished by electro-polishing.

Castings were represented by a front casing for a de Havilland Goblin engine, weighing 150 lb., and a reduction gear casing weighing 130 lb. for a Bristol Proteus engine.

A group of aircraft heat exchangers fabricated by dip brazing, included a radiator, an air/air cabin heat exchanger, an oil cooler, an air intercooler, and a fuel heater. Pressure vessels on display had capacities from 14 cu. ft. to 45 cu. in. for pressures as high as 3,300 lb./sq. in. An interesting development in aircraft construction, combining light weight with strength, was the honeycomb section displayed, the core being of hard temper foil 0·003 in. thick, bonded to facing sheets of strong alloy.

A coaming tube for the Canberra was shown, forming the structural portion of the fuselage surrounding the pilot, the cross tube supporting the seat. Particular interest attached to the complete engine for the Westland and Bristol helicopters, incorporating many aluminium alloy castings. A Comet III spar boom, machined from the largest extrusion at present made, was exhibited outside.

Road Transport

Vehicles were, of necessity, shown outside, and included the London Transport Executive's prototype Routemaster—a 64-seater, double-decker bus having an unladen weight of 6 tons 14¾ cwt., compared with its 56-seater predecessor of 7½ tons unladen weight. This vehicle has been developed as the standard replacement for the existing 8,000 buses, and for the conversion of trolley bus services to diesel operation. Another example of monocoque construction was a 35-seater B.O.A.C. coach, with a fully stress-bearing structure of aluminium alloy extruded sections and sheeting.

A National Coal Board tipper of 11 cu. ft. capacity was shown with a body which, although of extremely robust construction weighed only 10¼ cwt., while a bulk haulage vehicle developed in recent years, a bulk grain

Outside display of vehicles of aluminium alloy construction.

Everest equipment, including ladders, oxygen bottles and carrier and cooking vessels.

transporter with body and driver's cab in aluminium, represented large capacity container vehicles with low unladen weight. Completing the commercial vehicle exhibits was the familiar Land Rover station wagon, with body units comprising the floor, sides, ends, bonnet, mudguards, doors and top cover in aluminium alloy, assembled by spot welding using standard type resistance welders.

The famous Rolls Royce Silver Ghost motor car of 1906 vintage was displayed to illustrate the extensive use of aluminium in motor cars of that time, and it could be compared with a modern Silver Wraith saloon with all-aluminium coachwork.

As might be expected, since road transport is easily the largest single user of aluminium, the detailed exhibits in this section were many and varied. Complete engines were included, along with a motor-cycle and a self-contained light-weight pump for fire tenders, to mention only the larger items. Details such as pistons, carburetters, brake drums and door hinges illustrated the various methods of manufacture employed, and vehicle trim and bumpers showed the attractive finishes obtainable by electrolytically brightening and anodising super-purity aluminium and alloys based on it. More than 60 individual items were seen on this stand alone.

Marine Engineering

Most of the exhibits in this section also were outside, including the largest in the exhibition, moored in the Thames—an inshore minesweeper, H.M.S. *Altham*, kindly provided by the Admiralty. She is of 137 tons, and of composite aluminium/wood construction, and proved a very popular attraction. Alongside her was moored the well-known aluminium motor yacht *Diana II*, of 10·5 tons and in continuous service since 1931, a most convincing example of the durability of suitable aluminium alloys in marine service.

Other small vessels were shown in a large pool by the Royal Festival Hall, and included " Barnacle Bill," the earliest example of an aluminium-magnesium alloy lifeboat, constructed in 1934 and still in excellent condition. Three new lifeboats were also shown, including one mounted on all-aluminium welded davits. These lifeboats were similar in type but differed in details of construction, two having loose buoyancy tanks, and the other with built-in tanks making for great strength. An airborne lifeboat of the type dropped by parachutes to survivors, was of particular interest : these boats are designed to operate in any part of the world, whether polar or tropical. A 13 ft. speedboat on view was identical, except for colour, with that presented to H.R.H. The Duke of Edinburgh by the aluminium industry. The boat weighs 5½ cwt. and has a speed of 34 m.p.h.

A 66 ft. ship-to-shore gangway shown, weighing 30 cwt. and designed to carry a load of 19,500 lb. without undue deflection, was that used by H.M. The Queen at the opening of the Isle of Grain oil refinery. A lattice mast for a fast patrol boat was included, together with a jack staff and stanchion unit for off-shore minesweepers, and a 12 ft. high radar mast.

Apart from examples of standard sections for ship construction and cast sidelights, windows, and other shipbuilding details, three models were on view in the indoor display. That of the S.S. *United States* requires no comment, as the use of aluminium in this vessel—amounting to 2,000 tons—is now well known. The model of a cargo lighter showed a ramped type of craft for operation in very shallow water, and the other model was of a double-ended all-aluminium ferry to be used in the tropics. The latter craft will carry a lorry or two cars and 30 passengers.

Railways

One of the most impressive outside displays at the Exhibition was that devoted to two items of railway

coaching stock. A London Transport Executive surface car was one of a type now a familiar sight to many Londoners since 90 such cars were put into service on the District Line in 1951. A reduction in tare weight of about 14% was achieved, compared with similar stock largely built of steel, and careful tests have shown that a saving of energy consumption of about 12% is obtained. A number of the cars have an unpainted exterior finish and the car shown in the Exhibition was one of these.

One of the considerable number of cars for use as light-weight trains, being built at the Derby Carriage Works of British Railways, was also on view, with green painted finish. Low weight is important to obtain adequate performance with power units of moderate capacity, and aluminium is extensively used in construction and fittings.

Indoors, a section of one of the new aluminium railway cars for the City of Toronto was exhibited: there was also a model of a first class coach for the East African Railways. Thirty-six of the latter with integral body and underframe of aluminium alloy, have already been supplied, the low weight being particularly advantageous in the mountainous terrain where they are serving.

Railway fittings and components were exemplified by luggage racks, door locks and window frames, with a carriage door of the " slam " type which not only saves weight but avoids difficulties arising from corrosion of the interior surfaces. Other fittings included were vacuum brake hose couplings, emergency relay valves for compressed air braking systems which are electrically controlled, air engines which operate the sliding doors of subway and other types of electric railway, and the sliding doors themselves.

That aluminium is not only applied to rolling stock was shown by the examples of louvres built for engine compartments of diesel-electric locomotives, whilst an application of the material to steam locomotives was demonstrated by the casting used for a headlight of the type fitted by oversea railways. Other items of interest were a large cast lavatory floor used in oversea coaches, lighting fittings and fans, and a buffer utilising the principle of air-hydraulic cushioning.

To show that railway applications of aluminium have long been established in this country, a piece of aluminium panelling was included, which had seen service for 38 years on a Manchester to Bury electric line coach.

Building

The building field is a very important one for aluminium, but many of the applications are either very large, as in roofing, or of detail, as in rainwater goods, and therefore present problems to the exhibition designer. Both inside and outside the hall there were many items concerned with building uses.

Roofing was illustrated by corrugated and troughed sheeting, roof decking, and examples of welts and joints used in fully-supported aluminium roof cladding. Roofing tiles were also seen, while a recent important advance in building technique was shown in the shape of a panel of aluminium curtain walling. Windows of both casement and sash type were included, and also glazing bars and a glazed partition. An example of acoustic ceiling incorporated radiant panel heating and special lighting, while various types of aluminium ventilator could be compared.

Rainwater goods have already been mentioned; they were to be seen in variety. A street lighting column, handrails, fire escapes, insulating foil, nails, screws and other fasteners, scaffolding and fittings, a bus shelter—all were there. The A.D.A.'s outside ticket office was a small, round aluminium building, and the motor cars on display were housed in a temporary shelter made from aluminium scaffolding and aluminium corrugated sheet. Prefabricated buildings, so important for export, were shown by photographs and models.

Structural Engineering

A focus of attention outside the Hall was a 170-ft. aluminium alloy jib for a walking dragline, framed of extruded section and plate. A hangar door leaf, 50 ft. high × 25 ft. wide, one of 16 closing the end of a 200 ft. span hangar in Bedfordshire, was reared and supported on end and formed a landmark. A 30 ft. aircraft servicing tower had a transverse cantilever platform made of standard elements to permit the construction of a wide variety of tower and staging structures, the standard basic elements being welded and then assembled by galvanised steel bolts.

A military bridge cross-girder was shown with a continuous longitudinal metal-arc weld along the neutral axis of each web, to join two specially shaped extrusions and a stiffening diaphragm running the full length and rebated for easy assembly. The decking for this bridge was also included.

Completing the outside exhibits was an auto-dumper bucket constructed of plate, welded by the argon-shielded consumable electrode process, and weighing about 490 lb.

Structural exhibits inside were of necessity mainly models, including one of the double-leaf bascule bridge opened at Aberdeen in 1953, and two hangars—that for the Comet at Hatfield, with a clear span of 200 ft., and a transportable type for use without prepared foundations. An especially interesting application of aluminium was a quadrant for a slot aerial, made from curved sheet, castings and extrusions, the whole being about 10 ft. by 5 ft. This type of quadrant is used by the B.B.C. for V.H.F. sound broadcasting.

Electrical Engineering

Because of its high electrical conductivity (61% of that of copper) aluminium has been an important material in electrical engineering since it first became available. The electrical section showed aluminium usage in six main divisions—overhead transmission lines, low and medium tension lines for distribution, insulated cables for power supply, busbars and switchgear, components and cables for telecommunications, and windings. In each of these sections reference was made to the methods developed for making satisfactory electrical joints, and the exhibits demonstrated convincingly that this technical problem—which used to be considered a difficult one with aluminium—has been overcome in satisfactory ways.

The ability of aluminium to give long service was demonstrated by a number of exhibits of historical interest—such as overhead aluminium conductors after 40 years' service in various climates, and 660-volt insulated cables with aluminium conductor put into service about 1913.

The largest steel-cored aluminium cable yet made, weighing 4·77 lb./ft. and of 2·295 in. diameter, was on

view, as was aluminium-sheathing produced in several ways for power cables. The use of aluminium for conductors as well as for sheathing was foreshadowed by a 3 ft. 6 in. length of 0·4 sq. in. cable, weighing only 11¼ lb.; alongside it was a 0·25 sq. in. copper-cored lead-sheathed and armoured cable of conventional design and of equivalent current-carrying capacity, but weighing 25 lb. A wide range of busbars included flat, channel and tubular section up to 10 in. wide, with examples of bolted, welded and brazed connections and appropriate fittings.

Samples of aluminium parts in automatic telephone selector banks and a telephone cable joint box were also shown. In a range of co-axial cables was an exceptionally large one, 3⅛ in. diameter, for heavy duty, with an aluminium sheath. A cast rotor for a 30 h.p. motor on view weighed 2¼ cwt., in which the elimination of all joints on the short circuiting rings greatly simplified production. Windings included a small light-weight coil for a loud-speaker, giving improved reproduction at higher sound frequencies, and anodically insulated aluminium wire in an air-cored inductance for cross-over networks; light weight and reduced cost are the advantages gained. A small transformer was shown in which the weight has been reduced 50% by using anodically insulated aluminium wire windings, operating at 140° C., and special laminations. Methods of jointing single wires were displayed.

Outside electrical exhibits included drums of steel-cored aluminium conductor and all-aluminium conductor, a radar scanner and mast, and a large experimental transformer with aluminium windings.

Chemical Engineering

Recent and revolutionary advances in the joining of aluminium by argon-arc welding and self-adjusting-arc welding have aided immeasurably in the construction of chemical plant, as these methods do not involve the use of flux, and give particularly neat welds which—where necessary—can be readily dressed. This was illustrated by an aluminium pressure vessel fabricated in this way. An indication was given of the versatility of aluminium in exhibits varying in size from packing rings for towers to typical pipework fabricated by argon-arc welding. Castings were represented by filter press parts, accessories for a road tanker, and the bodies of such items as a colloid mill and a high speed mixer.

A fairly recent development was illustrated in the use of corrugated sheet to cover insulation on pipes: both protection and extra thermal insulation are provided. Heat exchangers are vital parts of the many chemical processes, and a high pressure contra-flow brazed aluminium type was one of the exhibits. Aluminium oil bursting discs in many sizes and types were also included.

General Engineering

This heading ,of course, can cover a very wide field indeed, and the exhibits included equipment used for such diverse activities as exploration—the 1953 Everest Expedition—fire fighting, mechanical handling, mining, printing, and the textile industry: applications in machine tools and precision instruments were also in evidence.

The National Research Development Corporation Ricardo steam engine, designed as a sturdy, light, adaptable unit for rural use in undeveloped countries was shown; aluminium is incorporated for the crank-

Assortment of aluminium bursting discs, including failed examples.

case, connecting rods, pistons and boiler drum. In contrast was the Rover IS/60, Britain's smallest industrial gas turbine engine yet to go into production, a single shaft unit developing 60 b.h.p. continuous rating; its light weight is gained by the use of aluminium alloys for all possible components.

The micro-optic alidade and micro-optic theodolite shown were fine examples of the use of both wrought and cast aluminium alloys in instrument construction, resulting in neat, sturdy, light-weight instruments. A display of fire-fighting equipment included pressure hose coupling, suction hose coupling, standpipe and dividing breech. A sack truck, a single aluminium casting weighing 32 lb. and able to carry a load up to 2 cwt. was shown with a hoist using die-cast aluminium alloy for its main components, and a compressed-air-driven 16 in. mining fan was a good example of the use of aluminium castings for a portable ventilating fan where lightness and durability are essential.

Other exhibits on this stand included printing equipment, textile machinery with bobbins and pirns, and cast items for machinery parts. A relatively new development was the full suit of thermo-foil heat reflecting clothing, to protect workers at furnaces and also fire fighters, the material being a cloth/aluminium foil laminate.

Agriculture and Food

The exhibits in this section were of considerable general interest to the average man with a bent for gardening, including as they did a large greenhouse, a portable pneumatic hedgecutter and a fruit picking ladder. The value of lightness and corrosion resistance was seen in a twin-wheel hoe and a seed-sower, in a portable agricultural weighing machine, and particularly in the case of a rotary insecticide duster. Dairy

Part of packaging stand showing beer barrels made by casting and argon-arc welding, argon-arc welded aluminium-magnesium alloy drums, and aluminium alloy bottle crates.

implements included milking machine buckets, a milk cooler, and two different types of aluminium milk churn —surely a perfect application for a light, hygienic metal.

On the food side, baking sheets and containers were seen, with ham and tongue presses and a brawn mould. In that branch of industry, partly food handling and partly packaging, which has turned so largely to aluminium, examples were shown of fish kits for dockside use, fish boxes for delivery to the shops, trays for fruit and confectionery, and meat boxes, all produced by folding or drawing, and mostly designed for neat stacking.

Packaging

This section attempted to cover the whole field of packaging, but each branch could obviously only be represented by a limited number of examples. A connected display of aluminium foil showed how advantage is taken of the main properties of foil—lightness, opacity, lustre, impermeability, pliability, perfect sealing and hygienic qualities—as a wrapping material. Besides plain foils there were examples decorated by printing and embossing—also cut foils and those laminated to other films : containers made from foil and examples of packaged products were included, as well as brilliant seals.

Among small containers were those made by impact extrusion, and drawn and seamed boxes for many applications. A rather specialised branch of packaging was shown in the collection of Aerosol containers, in which pressures may be over 100 lb./sq. in. Food cans for fish, beer and milk show the great potentialities in this field, should economic circumstances become favourable.

Many kinds of closure are made in aluminium, including those for jam jars, milk bottles and screw top bottles, and examples of these were shown. This is a field where aluminium is gaining much increased usage, through non-toxicity, freedom from rusting, and malleability. Large containers are very varied in type and purpose, and aluminium can be adapted to the varied requirements. Thus, there were shown cast beer barrels, the two equal halves assembled by argon-arc welding, and drums made from welded sheet. The largest exhibit in this section was a "Tote Bin," a rectangular container of 100 cu. ft. capacity, yet weighing empty only 2 cwt.

Consumer Goods

In this section many familiar things were on view, and it was interesting to note how many everyday objects are now made of aluminium. School chairs, a cast frame for a gas fire, an electric radiator, and a clothes drying cabinet exemplified the useful, and beautifully finished vases, military badges and costume jewellery, the decorative. Sports equipment included a billiards cue, a javelin, and arrows made from tube in high strength alloy. Perhaps many visitors were surprised to learn that the perambulator on view—of well-known make—was largely aluminium sheet, although they would be well acquainted with the aluminium refrigerator parts. Two sculptured heads by a prominent artist were made from sheet by beating and welding.

Perhaps the greatest interest on this stand centred on an all-aluminium pocket watch, weighing half-an-ounce ; only the springs and jewels were not of the metal.

Research

Having completed an inspection of the applications sections, the visitor's attention was next drawn to that devoted to research. The Aluminium Development Association is recognised as a research body by the D.S.I.R., and an impressive list was given of Universities, Technical Colleges and other Research Associations with which it works. A photographic display showed research work in progress on different aspects of aluminium technology—analysis, corrosion testing, welding, casting and other processes.

A few aspects of recent research were shown ; including sintered aluminium products, the chemical etching of aluminium panels for economy in the production of reinforced aircraft skins, and aluminium alloy bearings. The problem of keeping weight to a minimum while maintaining structural rigidity has been tackled in the recent development of an integral stiffened sheet by a rolling process which pressure-welds ribs on to aluminium alloy sheet in one continuous operation without loss of flatness : an example was shown. Many of the problems associated with the hot dipping process for aluminium coating of steel have now been overcome, and typical applications and samples showed the ductility of the coating.

Pictures, some in colour, traced the test work done by A.D.A. which established that aluminium structures could readily be protected against the most serious shipboard fires. For the mathematically minded, a series of panels summarised ten years' work at leading Universities on the design of efficient structural sections in aluminium alloy.

The Future

On the four sides of a model of the crystal structure of aluminium, the future of the metal and the industry were

described, and this formed a fitting ending to a viewing of the Centenary Exhibition.

The output of aluminium has doubled every ten years, and the demand continues to grow. As it enters its second century, the aluminium industry is already planning fresh programmes of expansion and application. Ore reserves are unlimited. New plants are envisaged in Central and West Africa, Brazil, British Columbia, Surinam, Yugoslavia and elsewhere. The Paley report estimates that production will reach six million tons by 1975.

In the first instance the additional aluminium will be required by those industries which are at present the principal consumers, and which are themselves expanding —the British motor vehicle industry for example. The improvement of roads in Britain, the modernisation of British Railways, new methods of building construction —each will demand more aluminium, and so will other developing industries—chemicals, packaging, and all types of consumer goods. For both economic and technical reasons, aluminium will be increasingly used as a conductor material in the electrical industries. Nuclear power stations, of which the first in Britain will go into service at Calder Hall, will provide ever more power, which means more machines and a fresh rise in productivity, all of it involving aluminium at each stage.

In the more distant future developments promise to be spectacular. The Prime Minister recently stated " We are moving into a new age ; a scientific revolution as decisive as the industrial revolution many years ago." Entirely new industries will be born as the era of atomic energy unfolds. Electronics, nuclear fission, chemical synthesis, micro-biological culture are some of the tools that will shape this future. Inventions as yet unimaginable will be made.

Aluminium is a young metal but the impetus that the aluminium industry has already developed will carry it into most of these future projects in one form or another. This 1955 Exhibition will be looked back upon as an event which opened the eyes of many regarding the progress made in the first century of the metal, and acted as a pointer to the possibilities ahead.

Magnesium Elektron, Ltd., 1934—1955

Magnesium Elektron Ltd., is this year celebrating the 21st Anniversary of its establishment as a company. To mark the occasion, the Company invited representatives of all its licensees in Great Britain, Europe, the Commonwealth and the U.S.A. to visit the Works at Clifton Junction, Manchester, on 16th and 17th June.

With the exception of the Commonwealth Aircraft Corporation of Australia, every licensee firm was represented. Short papers were read by members of the staff of licensees and of M.E.L., covering the more recent developments in the magnesium field ; discussions were held ; and, by courtesy of all the leading U.K. founders, fabricators and users of Elektron magnesium alloys, a remarkably representative Exhibition of some of the finest specimens of magnesium products made in Britain was assembled.

Because magnesium—being 40% lighter than aluminium—was a metal whose alloys had become vitally important to the R.A.F. re-armament programme, as well as to industry generally, M.E.L. was created in 1934 to acquire from the I.G. Farbenindustrie of Germany, the largest producers of magnesium in the world, the process for the thermal electrolysis of anhydrous magnesium chloride to give magnesium metal. Its first plant of some 1,500 tons per annum capacity of magnesium metal and alloys, went into production in December, 1936, and the Company was at once called upon to expand further to meet the urgent demands of the Air Ministry.

An additional 2,500 tons per annum capacity was added in 1937, and a further 5,000 tons in 1941. In that year, M.E.L. was asked to design, supervise the erection of, and operate a 10,000 ton per annum plant to be built in N.E. Lancashire for the Ministry of Aircraft Production. This plant was the largest producer of magnesium metal and alloys in the British Empire. In 1941, too, M.E.L. was called in by the U.S. Government to design, assist in the construction of, and start the operation of the largest magnesium metal and alloys plant in the world—55,000 tons per annum—at Henderson, near Las Vegas in Nevada.

Throughout its history, the development and supply of magnesium alloys of the highest quality, together with relevant know-now, has been the Company's sole objective, since only in this way could industry be encouraged to make greater use of magnesium. During the war years, research was mainly devoted to immediate problems, but following the war great progress has been made in developing new ultra-light alloys possessing the increased mechanical properties demanded by the aircraft and aero engine industries. The initial discovery that a small addition of zirconium causes an intense grain refinement of magnesium was made by Professor Sauerwald, of the I. G. Farbenindustrie, in 1938, but it took M.E.L. many years of lengthy and complex chemical and metallurgical research to find practicable methods of alloying this element (problems which had been abandoned by the I.G. as insoluble). With the help of certain U.K. licensees, M.E.L., in early 1947, was able to introduce commercially a series of magnesium-zirconium-zinc and magnesium-zirconium-zinc-rare earth metals alloys for airframe and aero engine use, respectively. The former alloy gave considerably higher and more uniform strength at normal temperatures, and the latter gave designers the higher creep strength, at operating temperatures of up to 250° C., which was vital if the ultra-lightness of magnesium was to be utilised in engines of increasing thrust.

The success of these alloys—now standard aircraft and aero engine materials—and more recently of the magnesium-zirconium-zinc-thorium alloys, which give still higher strengths at operating temperatures up to 350° C., has led a number of companies at home and abroad—26 in all— to take out licenses to use M.E.L.'s patented processes, and so has enabled M.E.L. to earn substantial sums in hard currency. The importance attributed by M.E.L.'s licensees to these developments is shown by the fact that, with only one distant exception (Australia), all sent senior representatives to the Anniversary Meeting.

Progress in Metallurgical Research

A Review of Exhibits at the National Physical Laboratory Open Day, 1955

ON Friday, May 20th, the National Physical Laboratory held its annual Open Day. It was attended by more than 2,000 visitors, an attendance larger than usual and indicating the continued and growing interest of industrialists, technicians and scientists in the work of this the largest research organisation within the Department of Scientific and Industrial Research.

Whilst walking from one division to another, one could not help but notice the interdependence of the work in the various divisions, and how a particular technique developed in one can be useful in another. One of the great advantages of an institution like the N.P.L. is that work in many new fields of scientific research goes on side by side.

It is intended in this article to describe briefly some of the items of scientific work of particular interest to metallurgists, which, it is hoped, will encourage discussion with workers in similar fields. The items of metallurgical interest might be grouped as follows: (i) investigations into the mechanism of the behaviour of metals and alloys under specific service conditions; (ii) the verification of theoretical concepts, such as those accounting for brittle fracture and the inception of fatigue cracking; (iii) determination of the physical properties of certain metals and alloys in order to satisfy a growing need for information in certain branches of engineering; and (iv) development of new techniques and associated equipment.

Grain Boundary Embrittlement

A systematic study of the effect of alloying elements on the strength properties of high-purity iron, which has been in progress in the Metallurgy Division of N.P.L. for the last eight years, has led to the observation that quite small quantities of certain impurities such as oxygen, nitrogen and phosphorus, can have a big influence in producing embrittlement in iron after appropriate heat treatment. This embrittlement is caused by intercrystalline weakness which does not appear to be associated with the precipitation of a separate identifiable phase in the grain boundaries.[1]

Considerable attention has been given in the past year to a study of the factors governing the incidence of intergranular brittleness. For a given composition the occurrence of this form of weakness depends on the heat treatment. The results for iron containing 0·01% of nitrogen showed the effect of increasing the rate of cooling from 950° C. on intergranular failure.[1] Weakness developed in this alloy after heating for a very short time in a temperature range around 700° C. followed by quenching. If slowly cooled from this temperature range, the weakness was not present, and if rapidly-cooled material were reheated to a temperature above this range, such as 900° C., or to a temperature below the range, such as 400° C., the weakness was wholly or partially removed. Intercrystalline embrittlement is more readily revealed at lower temperatures and material behaving normally in a tensile test at room temperature may have reduced strength and break with an intercrystalline fracture at the temperature of liquid nitrogen (−196° C.). Work on single crystals of high purity iron show that the brittle cleavage strength of the iron crystal increases with fall in temperature, whilst the brittle strength of the boundaries decreases as the temperature is lowered.

Similar effects have been observed with additions of oxygen above about 0·003% and with phosphorus in amounts up to 0·30%. In the latter case, embrittlement after heating for a very short time at 700° C., followed by rapid cooling, is such as to render material so weak at room temperature that it can be broken with a tap with a hammer. There is no need to stress the importance of these results insofar as they might lead to a better understanding of the causes of failure of certain steel structures at low temperature, although it should be noted that embrittlement of this type may be largely counteracted by carbon and manganese in amounts normally present in steels.

In some respects the brittleness occurring in the above iron alloys, after appropriate heat treatment, resembles a form of brittleness occurring when antimony is added to copper in quantities less than are required for saturated solid solution[2]. The addition of antimony causes the alloys to break along the crystal boundaries, the brittleness being much increased as the temperature of test is lowered. Investigations of this phenomenon by impact tests showed that brittleness set in at temperatures where, according to the equilibrium diagram, there should be no possibility of a precipiate being present. Further, it was found that the transition temperature from brittle to ductile failure was raised by increasing the antimony content of the alloys, and that, on being heated, the alloys go through a range of maximum toughness at about 300° C., above which the tendency to intercrystalline fracture again increases. No precipitate which might cause brittleness could be observed in these alloys, although a faint grain boundary film was detected which was considered to be due to equilibrium segregation, that is, a concentration of antimony atoms in the grain boundaries of a solid solution.

Physical Changes in Metals under Fatigue Action

Of special interest is the modification made to a fatigue machine to enable the applied cyclic stress to be progressively increased as the test proceeds. This machine has been used to study the effects of strain ageing processes during fatigue. The procedure was to increase the applied stress from a value below the endurance limit, based on 10^8 cycles, at a rate of 10^{-4} to 10^{-1}

lb./sq. in./cycle for a cyclic speed of 2,000 c./min. The nominal stress at which the specimen fails is then observed and the relationship between this value and the rate of applying the increased load can be determined. It was shown that materials capable of strain-ageing, e.g. freshly quenched commercially pure aluminium (99·5% Al) and quenched iron, showed similar understressing characteristics, in contrast to the other materials tested.

Experiments have also been made which showed that chemical changes in a copper + 0·05% silicon alloy in the form of a precipitation product take place more quickly when subject to cyclic stressing at 325° C. than when heated in the unstressed state. This is thought to be due to an increase in the rate of diffusion of oxygen and silicon. To test this theory further it is intended to apply a quantiative radioactive tracer technique using a layer of irradiated silver to determine the effect of fatigue stress on the self-diffusion coefficient of this metal. It has been suggested that the ratio of the values with and without stress is a measure of vacancy concentration changes during fatigue, and has a practical bearing upon the idea that excess vacant sites may coagulate in some way to form voids and finally cracks on a micro scale.

A special X-ray technique has also been developed to study progressive changes within the specimen which might govern the formation of a crack during fatigue testing and that have so far passed unobserved. This is made possible by the use of a finely focused beam of partially monochromatised X-rays to obtain low angle scatter from selected small areas.

Some interesting observations have been made on the effect of stressing a specimen of polycrystalline copper foil. After a very small tensile strain a number of streaks appeared in the low angle diffraction pattern from individual grains. When subjected to progressive amounts of fatigue stressing, the low angle streaks grew in length and intensity. A tentative interpretation of this is that the streaks correspond to an oriented array of small holes in the specimen, the change in size and intensity of the streaks indicating a change in size, number and distribution of the holes.

Steels for New Power Stations

Data on the creep and relaxation properties of steels used in modern steam power plant are of increasing importance to such bodies as the British Electrical Authority, and to designers of steam power plant in general. Interesting developments of the work in progress in the High Temperature Mechanical Properties Section of the Metallurgy Division are that creep and rupture tests, over periods of time extending beyond 10,000 hours, are being made on material cut from components such as steam pipes, superheater tubes, forged turbine rotors and cast turbine casings. These data were shown in the form of graphs of temperature against time for specific creep strains and rupture at specific stresses. The range of temperatures investigated included the normal expected working temperatures of about 560° C. for ferritic steel and 625° C. for austenitic steels, and the stresses applied were of the order 3, 5 and 7 tons/sq. in. Relaxation data were shown as graphs of temperature against time to reach specific residual stresses under conditions of constant total strain, i.e., conditions simulating that of flange bolts in service. The falling stress was measured automatically by a trigger technique previously described in this Journal.[3]

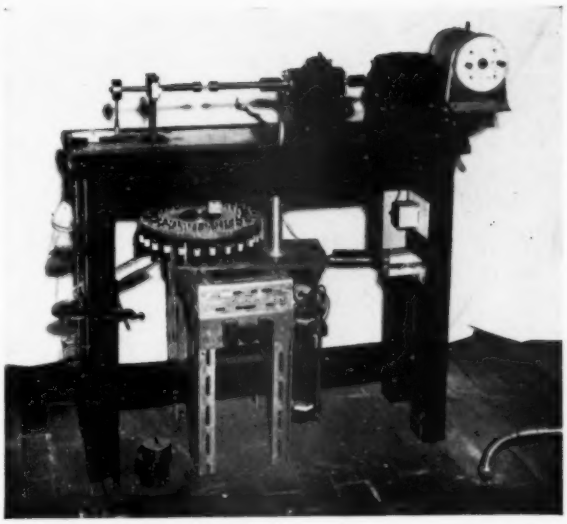


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Fig. 1.—Rotating bending fatigue machine modified for progressively increasing the load by means of a slowly rotating electromagnetic feeding device.

The material for these tests was from 1, 2 and 4 in. diameter steel bar stock, from which corresponding sizes of bolts were made.

Equipment for Creep Tests up to 1,400° C.

Various modifications have from time to time been made to creep test equipment, in order to overcome difficulties associated with the demand for data at very high temperatures, such as are required in connection with gas turbine engine and rocket developments. The equipment normally used was suitable for temperatures up to 800° C., and a solid head extensometer in conjunction with an adapter and shoulder test-piece could be used for tests up to 1,000° C. For still higher temperatures, up to 1,200° C., an adapter/extensometer assembly made of Nimonic 80 could be used for short periods of test, up to about 100 hours, using conical ended test-pieces. This design of test-piece was intended to simplify the making of test-pieces in materials difficult to machine and grind. A similar assembly, made in sintered alumina, was tried unsuccessfully for tests up to 1,400° C., and to improve its strength a similar arrangement, using an adapter and test-piece with screw threads ground by an ultrasonic pulse technique, was tried. The present arrangement, which shows promise for tests in the range 1,200–1,450° C., is to use a small test-piece with elongated shoulders. This has a gauge length of 28 mm. and is 7 mm. in diameter, with approximately ½ in. diameter shoulders cut straight and parallel to simplify grinding. A small electric furnace, 2 in. × 3 in. diameter, with ½ in. diameter bore, having a 10% rhodium-platinum wire (18 s.w.g.) winding on an alumina tube packed in alumina powder, fits round the specimen. The design is such that little heat is lost to the split shoulders of the test-piece, which can be gripped by normal type metal adapters. A disappearing filament optical pyrometer focused on to the gauge length of the specimen provides a direct reading of its temperature.

Constitution of Some Titanium Alloys

A series of photomicrographs illustrated the work undertaken to determine the constitution of titanium-

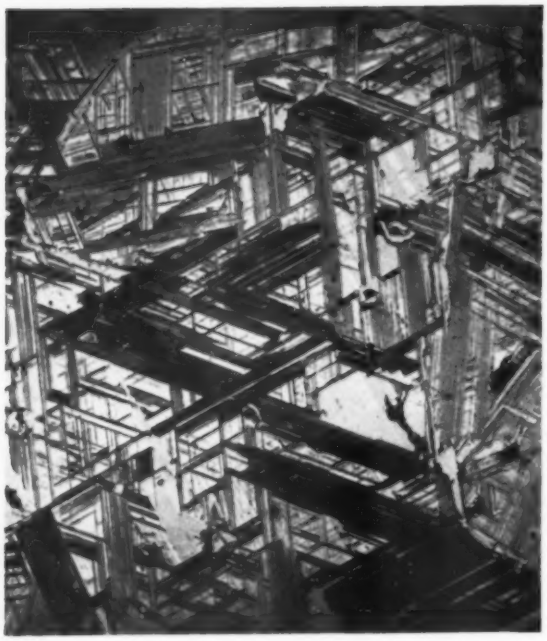

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Fig. 2.—Alpha (hexagonal) solid solution of oxygen in titanium and cubic TiO Etched in 0.5% HF, 1% HNO_3. × 500.

oxygen[4], titanium-iron-oxygen[5] and titanium-aluminium-oxygen alloys. Oxygen is a normal impurity in commercial titanium and it is important, therefore, that its effects on the constitution and on the mechanical properties of titanium alloys should be known. Iron and aluminium were selected as alloying elements because the former lowers and the latter raises the *alpha-beta* transformation temperature of titanium and both are constituents of some commercial alloys.

The titanium-oxygen system is characterised by the extensive range of the *alpha* phase (hexagonal) which extends to about 12 wt.-% at room temperature. In alloys of this composition the *beta* phase cannot be retained by quenching, although transformed *beta* may be recognised micrographically. In the middle composition range (12–24 wt.-% oxygen) a duplex field of hexagonal *alpha* and cubic TiO provides some interesting microstructures, as shown in Fig. 2.

In the titanium-iron-oxygen system, the *alpha* and *beta* phases are restricted at all temperatures, the extent of the *alpha* + *beta* phase field decreasing with falling temperature between 1,100° and 650° C. At 550° C. all alloys investigated, except those in a restricted *alpha* field, consist of *alpha* and ferrite.

The progressive addition of oxygen in the titanium-aluminium-oxygen alloys raises the temperature of the *alpha-beta* transition and also increases the extent of the *alpha-beta* field.

Heats of Formation of Alloys

Thermochemical data of alloy formation can be usefully applied to practical problems such as the production of commercially used alloys by thermal reactions, and are of special interest at the present time in the study of processes for the production of alloys of titanium by the reduction of titanium oxide with aluminium. Heats and entropies of alloy formation can also be used to determine the position of phase boundaries at low temperatures where other methods are impracticable. Heats of formation of solid alloys have been determined previously by calorimetric difference methods from heats of solution in acids or mercury, or from the temperature coefficients of electromotive force or vapour pressure. These methods, when evaluated for heats of alloying, are neither very accurate nor reliable, and two new calorimeters have been constructed to enable the exothermic and endothermic heat of alloying, respectively, to be determined directly. In the former case, a mixture of powders of the two component metals (e.g., titanium and aluminium) is heated by a small molybdenum wound furnace, within the calorimeter, until alloying takes place[6]. The electrical energy applied is measured by means of precision instruments and subtracted from the total heat evolved.

Details of the calorimeter are shown in Fig. 3. The compact powder mixture *A* is suspended by a 0·25 mm. molybdenum wire within the furnace, which consists of a molybdenum winding *B* insulated by alumina bushes *C* from the molybdenum framework *D*, surrounded by ten radiation screens of 0·03 mm. nickel foil *E*. The furnace hangs on a 1 mm. molybdenum wire, and is enclosed in a hollow cylindrical aluminium block *F*, the lid of which is fastened by four brass studs *G*: the gas outlet holes *H* pass through the lid. The block is suspended by linen threads *J* within a cylindrical brass vacuum-container *K* fitted with an O-ring seal *L*. The container is connected to a rotary vacuum pump and a McLeod gauge by a tube *M* which is shielded from direct radiation by a brass bridge *N*. This tube also holds the container, which is immersed in a water bath, thermostatically controlled at 25° ± 0·01° C. One end

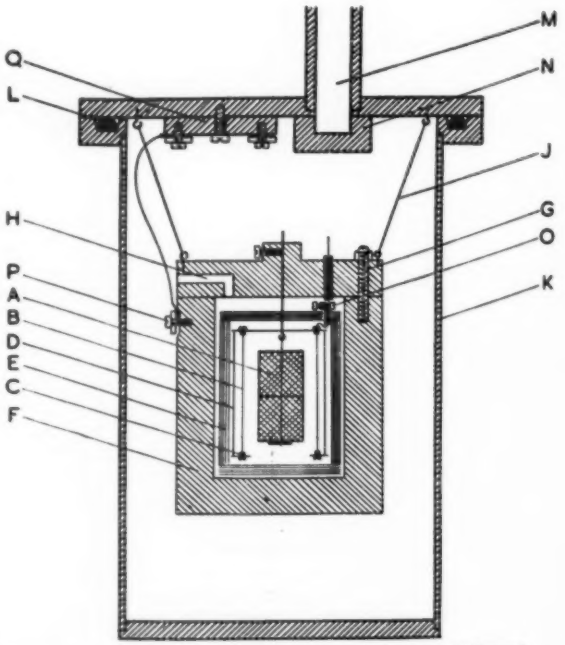

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Fig. 3.—Calorimeter for the determination of exothermic heats of formation of alloys.

of the furnace winding is joined to the molybdenum framework, the other end is connected by a steel terminal O to a 0·5 mm. copper wire, which is carried by a silica tube through the lid of the aluminium block. The furnace and block are earthed to the brass container by copper wire. Ten copper-Eureka thermocouples in series have their hot junctions at representative positions on the surface of the aluminium block. The soft-soldered junctions are clamped to the surface at P and the cold junctions to the brass block Q.

The procedure is to load the calorimeter, immerse in a thermostat bath and evacuate to 0·003 mm. Hg pressure. When a uniform temperature has been attained within the calorimeter, the furnace is switched on to bring up the temperature of the compact to that at which the reaction is known to start. This is indicated by a sudden increase in temperature, which is measured. The furnace is then switched off and the reaction increases the temperature of the compact by several hundred degrees. The temperature of the aluminium block rises and the thermopile potential is measured until a maximum value is reached after about one hour. On the following day, when the calorimeter is again at a uniform temperature of 25° C., an amount of electrical energy is put into the furnace which will raise the block to the same maximum temperature as in the reaction run. The difference between the input electrical energy in the reaction and calibration runs gives the energy evolved by the reaction.

A second calorimeter has been developed to determine the endothermic heats of an alloy. In this case the powder compact of the two different metals being alloyed, such as iron and chromium or gold and nickel, is enclosed in a shell which is heated up and held at a constant high temperature and then the reaction can proceed at a convenient rate, say, to completion in 1½ hours. A temperature difference between the shell and the compact is measured as this reaction proceeds. When this part of the experiment has been completed, the calorimeter is allowed to cool down to room temperature, and the outer shell is again electrically heated in such a way as to reach the same temperature-time sequence. In the latter case there is no heat absorption due to the reaction, and the heat energy equivalent to the area between the two curves is the required endothermic heat.

New Metallurgical Techniques

Reference has already been made to certain new techniques such as the measurement of diffusion coefficients by radioactive tracers and to low angle X-ray scatter in connection with the study of some fundamental aspects of fracture fatigue. A number of other items, however, are also of interest to the research worker.

The use of autoradiography in metallography was illustrated by its application to a cast copper-1·5% antimony alloy. The specimen was irradiated in the Harwell pile, the copper activity allowed to decay and an autoradiograph taken of the remaining antimony activity using a stripping film. It was found that improved resolution was obtained by using a thin formvar protective film over the specimen, allowing a wet mounted stripping film to be used. The radioactive antimony rich constituents then appear as dark areas in the developed film, and can be compared with the photomicrographs of the same area.

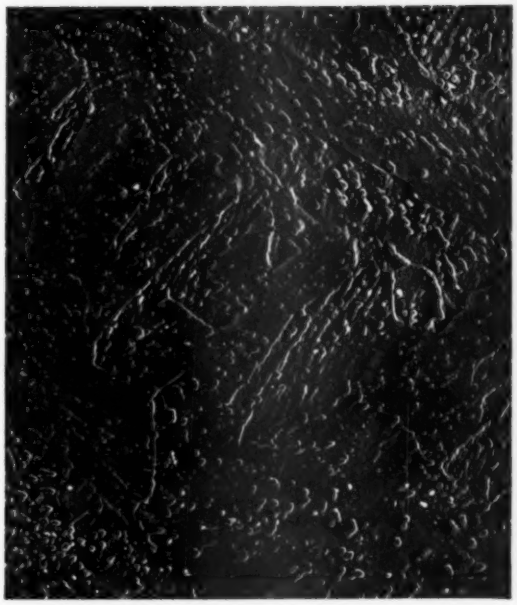

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Fig. 4.—All-metal replica of a tempered steel. × 15,000

A useful development is a direct-reading attachment for use with the Hilger spectroscope when analysing various materials, including those which give rise to complex spectra, e.g. steels and titanium. The attachment is similar to that developed by the British Non-Ferrous Metals Research Association, in that exit slits sited in the focal plane of the spectrograph direct the light from selected lines to photoelectric multiplier tubes. Each tube produces a photocurrent proportional to the intensity of the light falling upon it. This photocurrent is then made to charge a condenser, the voltage developed being directly proportional to the light intensity integrated with respect to time. The ratio of the voltages produced by the analysis line and an internal standard line is then determined, and the result translated directly to percentage of alloying element by means of a standardisation graph or by means of a prepared working graph. The attachment on view had four exit slits and could, therefore, be employed for the determination of three elements simultaneously.

In electron microscopy, metal specimens are usually studied by examining in transmission a thin replica which reproduces the surface topography of the specimen. It had previously been shown that an improvement in resolution and contrast could be obtained by shadowing the formvar replica with a heavy metal such as gold, platinum or chromium. The impression obtained, however, is still negative with respect to the original surface, and this makes interpretation difficult. A method of producing a positive evaporated all-metal replica has now been developed, in which the metal surface under examination is first coated with a thin film (about 20 Ångstroms) of a hydrophilic material such as boron oxide. This process is carried out in *vacuo* immediately prior to the deposition of the shadowing metal (gold-palladium) and a backing film of aluminium (75 Ångstroms). On removal of the specimen from the vacuum chamber, it is possible to float off on the water the composite replica film, the resolution of which is

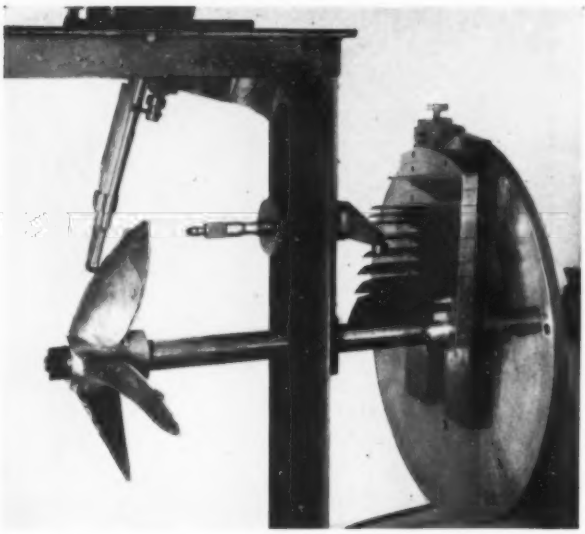

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Fig. 5.—Model propeller profiling machine.

limited by the grain size of the metal used in the preparation, which is usually better than 100 Ångstroms.

A technique has been developed for the preparation and manipulation of single crystals required for the determination of their elastic constants as part of a study of the factors contributing to the cohesive forces in binary alloys of copper with zinc, gallium, germanium and arsenic. The equipment consisted of (i) apparatus for the growing of single crystals ¾ in. in diameter and 4–8 in. long, by the Bridgman method; (ii) X-ray camera and jig for cutting the crystal to expose two (110) faces about 1–2 cm. apart, and (iii) X-ray camera and jig for aligning each cut face in turn in a lapping machine, after removing the worked layer electrolytically, to within 1° of the 110 face, for the final process of lapping each face parallel to the other. This type of test-piece enabled all three elastic constants of the cubic system to be determined by an ultrasonic pulse technique.

Heat Transfer Measurements

Heat transfer problems with structural panels such as those used in the walls and roofs of buildings, or forming the pressurised cabins of aircraft, particularly when the exposed surfaces are at a sub-zero temperature, are receiving increased attention in the Physics Division. A simple guarded hot box to measure heat transfer through these panels (3 ft. square) was on view. It had been modified to operate at a cold face temperature of −78° C. (−108° F.) by covering the upper face of the panel to a depth of about 2 in. with lumps of solid carbon dioxide. The test panel forms the lid of a shallow cork box which can be heated internally by an electric heater to maintain the other face of the panel at a room temperature of 15° C. (59° F.). Data have been obtained for various insulated wall panels and panels incorporating metal ribs similar to those used in aircraft structures.

Another aspect of the same type of problem, namely, an increasing demand for data on the thermal conductivity of various heat insulating materials at the low temperatures required when designing low temperature equipment used for the transport and storage of liquefied gases, or for the insulation of aircraft, has led to a modification of the standard 12 in. guard hot plate apparatus as used at the N.P.L. For this purpose the cold plates normally cooled by circulating liquids were replaced by plates cooled directly with liquid nitrogen, solid carbon dioxide or ice. Data have been obtained for expanded perlite, cellular ebonite, various expanded plastics and glass wool, at cold face temperatures of −195° C. (−319° F.), −78° C. (−108° F.) and 0° C. (32° F.) and a hot face temperature of about 15° C. (59° F.).

Items of More General Interest

Attention has been given primarily to the work of the Metallurgy Division and it is only possible to refer briefly to some of the 200 or more items of the work of the other divisions which were on view.

In the Ship Division new methods of manufacturing model propellers have been introduced to meet the standard of accuracy required when a full-size propeller is scaled down as a model. One process involved the use of spring steel templates accurately cut to enlarge the drawings of the expanded sections of the blade. These templates are then bent to the correct cylindrical arc for the second stage of cutting the forms on the screw blades in a special profiling machine using a pneumatically operated small fly cutter. The Aerodynamics Division has now a special workshop for the manufacture of steel model aerofoils and wings by the tangent-plane machining technique.

The work in the Light Division, leading to improved methods of producing diffraction gratings, has made possible the commercial availability of grating spectrometers and is expected to encourage development in infra-red spectroscopy. Compared with the use of prisms, gratings provide a much wider separation of wavelengths, and achieve correspondingly higher resolving power. The use of diffraction gratings to produce moire fringes provides an optical vernier capable of measuring linear displacements to a high order of accuracy. This has interesting possibilities as a method of controlling machine tools electronically.

Highly accurate dimensional measurement is a function of the Metrology Division, which has developed a comparator capable of measuring the pitch errors in "fir-tree" root serrations of gas turbine blades at a fast rate and with high accuracy. Pneumatic gauging techniques have also been developed to enable measurements to be made of the order of 10^{-6} in. (0·025 μ) and have been applied to check variations over the surface of a 3½ in. cube of tungsten carbide made by sintering a compact containing additions of 30% by volume of cobalt. This cube weighed about 10 kg. and was used to determine the density of mercury to an accuracy of one part in one million. It was necessary for the volume of the cube to be known accurately, and the cube was ground and lapped so that each face was flat and parallel to within 1/100,000 in. at the faces, and with angles square to within 0°½".

These examples serve to indicate the interesting work in progress in the Laboratory.

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Silver Jubilee of the London Laboratories of the B.N.F.M.R.A.

The British Non-Ferrous Metals Research Association was recently honoured by a visit from H.R.H. The Duke of Edinburgh on the occasion of the Silver Jubilee of the setting up of its Laboratories in Euston Street, London. The Association has made many notable contributions to technical progress in the non-ferrous metals field as will be seen by the following references to a selection of them.

Front block of the B.N.F.M.R.A. Laboratories.

THIS year marks the Silver Jubilee of the occupation by the British Non-Ferrous Metals Research Association of its premises at Euston Street, London, N.W.1. Founded in January, 1920, under the aegis of the Department of Scientific and Industrial Research, the Association's Head Office was situated in Birmingham until 1929. In the later years of this first decade, a small laboratory was rented in the Metallurgy Department of the University at Edgbaston, but the Association's main researches were carried out in the laboratories of universities, government departments and industrial companies, with whom research contracts were placed. As the Association grew, it became of increasing importance to establish its own research laboratories, where scientific teams could be built up and provided with the tools of their trade, so that research and other activities could be undertaken from one centre. Accordingly, early in 1930 a small factory building was acquired in a convenient location near Euston Station, in London, and around this site the present more extensive premises have grown.

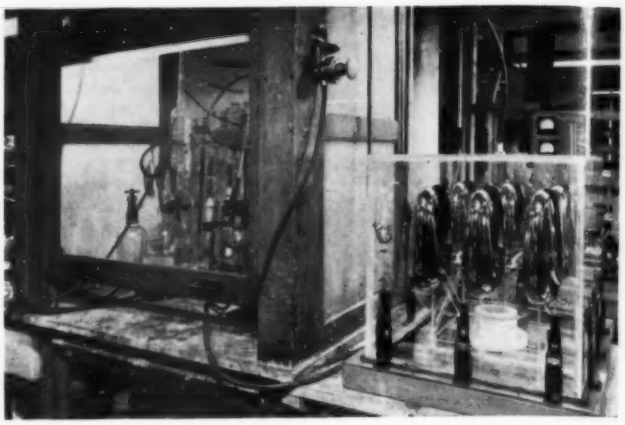
The 20 founder-members—mainly Midland manufacturers engaged in the brass and copper industry—had been augmented to a total of 159 by the time the move to London was made, and to-day the membership stands at over 600 and includes the producers of the main non-ferrous metals—mainly situated in Canada, Central Africa and Australia—and the manufacturers of semi-finished products (both cast and wrought) in these metals and their alloys. There has been a large expansion in that section of the membership consisting of firms engaged in manufacturing operations in the heavy and light engineering industries who are interested in the use to which non-ferrous metals are put in the ultimate products made for sale.

Research associations raise their incomes in various ways. In many cases the entire industry contributes through a levy, but in the non-ferrous metals industry the income comes partly from subscriptions from individual firms, and partly through dues collected from various trade association on behalf of their member-firms. All industrial income subscribed by members operating in the United Kingdom qualifies for Government grant, but that received from overseas members does not. Grant earning income rose from £15,800 in 1930 to £23,600 in 1945, but the last 10 years have seen a rapid rise to £70,600 in 1954, when the total income (including £22,000 in Government fees), reached £140,000, compared with £25,000 in 1930.

Laboratories

The original factory premises, with a floor area of about 10,000 sq. ft., served to house the Association's work until 1937, by which time the Council was convinced of the success of the experiment of establishing a central laboratory in this particular neighbourhood. Adjacent property, occupying about 10,000 sq. ft. of land was then purchased and partly demolished to build a second block, again of about 10,000 sq. ft. floor area. The war prevented any further clearance of the site and resulted in the destruction by fire of the original building. After various temporary measures to meet this situation, adjacent factory premises were bought on a long lease, and approximately 20,000 sq. ft. adapted to the Association's purposes. In 1950 the original war-damaged block was reconstructed, and the Association now has some 43,000 sq. ft. of floor space in use, with a now largely vacant site of 5,000 sq. ft. of ground area available for development.

Rolling thin copper strip by pouring copper powder between a pair of rotating rolls.



Accelerated corrosion test, using an atmosphere of moist sulphur dioxide, used to assess the behaviour of nickel-plated bumper bar over-riders.

The laboratories are equipped with the plant, apparatus, and instruments appropriate to a modern metallurgical research establishment, a total sum of the order of £250,000 having been spent in the provision of laboratory buildings and their equipment.

Organisation

The Association's affairs are controlled by a Council elected from among the representatives of members. The Council is served by two committees, the Finance and General Purposes Committee, and the Research Board, which is responsible for the research programme.

The Research Board is aided by five policy-forming committees whose responsibilities are, respectively: aluminium, magnesium and their alloys; copper, nickel and their alloys; lead and tin; zinc and galvanising; and chemical and electro-chemical finishes. Specific researches are carried out under the guidance of small Research Committees drawn from member-firms with specialised knowledge of the subject under consideration.

Internally, the Association is organised in four departments, namely, research, liaison and technical service, information and library, and administration, the ratio of expenditure on the first three being to-day approximately 65: 22½: 12½.

Research Achievements

Over 100 major research projects have been carried out in the Association's laboratories, and elsewhere on its behalf, during the last 25 years, and it is impossible to do more than refer briefly to some of the more outstanding investigations. Much of the research work of the Association consists of long-range studies of the basic facts underlying certain metallurgical processes, and it is interesting to note that new knowledge obtained in such investigations has not infrequently led to immediate modifications of the process in question, with benefit to both manufacturer and consumer. There are also, of course, short-term investigations of urgent practical problems.

Improvements in Quality

Ingot casting, which is the first stage in the production of a wrought product, has been studied with a variety of materials, for a high ingot quality is the first essential of a high quality rolled or drawn material. Much of the work which led to the publication, in 1934, of "The Casting of Brass Ingots," was carried out before 1930, but the subject has not been neglected since that date. Nor has that of sand casting, where the influence of gas reactions on the soundness, pressure tightness and mechanical properties of the casting has been studied.

As welding is closely related to casting, many of the metallurgical problems encountered, particularly concerning gas reactions, are common, and the work done on the weldability of aluminium and of copper base alloys has, in fact, run parallel with that on sand castings —to their mutual benefit.

The Association has made considerable additions to our knowledge of the effect of impurities on metals, notably in the case of copper alloys, where work carried out at the N.P.L. during the first decade was supplemented during the war by more detailed studies of the effects of such elements as selenium, tellurium and bismuth, which were found to be contained in some of the copper that had then to be used. Later work has shown that the permissible tolerances for lead and bismuth in some copper alloys are extremely low compared with the figures for pure copper. The Association has recently developed a method for the fine refining of scrap copper which allows lead contents of the order of 0·005%, or less, to be reached within the normal 24-hour fine refining cycle, instead of the 48 hours normally required.

Several of the complex aluminium alloys are quite as strong as many structural steels, they can be extruded to shape, and they are much lighter than steel. On the other hand, their transverse ductility is lower, and exhibits at the recent Silver Jubilee Open Days referred to work in hand to find the factors controlling this property. The work is coupled with investigations into the control of the size of the intermetallic particles in the billets used for extrusion.

The corrosion of copper water pipes has been engaging the Association's attention for some years, because there are a few waters in the U.K. where copper housing tube is liable to fail by pitting. The presence in the water of a natural corrosion inhibitor appears to protect the copper in the vast majority of hard waters. On the metallurgical side, the presence on the inner surface of the tube of a film of carbon, such as might result from bright annealing, renders the metal liable to attack. Reference may also be made at this stage to the research on galvanised steel which has shown the best conditions to ensure good service in different kinds of water supply.

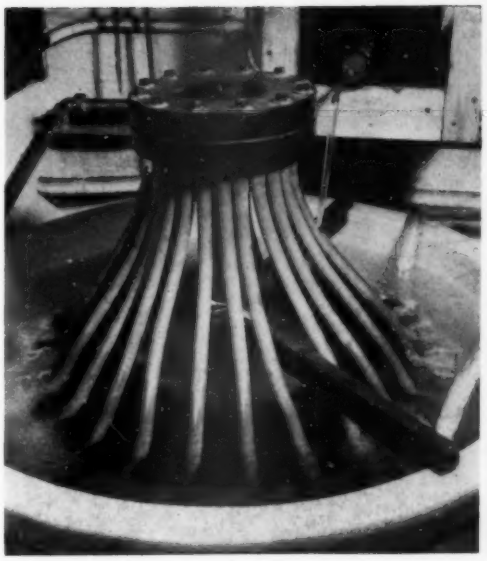
Improvements in Processes

Arising from the work on gas solubility and gas reactions it has been found that certain sand castings can be considerably improved by the deliberate introduction of the right sort of gas holes in the right places. For instance, bronze valve bodies can be made pressure tight by the introduction, by means of the metal/mould reaction, of gas bubbles which are fairly uniformly distributed throughout the casting, and not connected with one another: in this way shrinkage defects are avoided. In the aluminium alloy foundry the metal/mould reaction is a nuisance, and methods have had to be devised to suppress it. Important improvements have been made in the feeding of shrinkage in castings by the introduction of thermally insulating feeder sleeves, whose development was paralleled by industrial development of exothermic feeder sleeves.

In the field of protective coatings, much complaint is heard to-day of the quality of nickel-chrome electroplated finishes, particularly those applied on external surfaces, such as automobile components. These complaints coincide with the turnover from buffing the nickel undercoating to the use of bright nickel plating processes, and also with the shortage of nickel in recent years. Cracking has been one of the main defects noted on many samples of commercial nickel plate examined, but the operation in the Association's laboratories of two electroplating lines, running as production plants plating bumper bar over-riders, has shown that, when properly handled and controlled, the two most commonly used proprietary solutions produce deposits of good appearance and free from cracks.

Research aimed at enabling the thickness of chromium plating applied for decorative purposes to be increased without loss of lustre or the formation of cracks, may lead to enhanced protective value of the chromium, and, possibly, to economies in the use of nickel for the undercoat. Existing methods for electroplating on aluminium have been examined, and modifications designed to improve the adhesion of the deposit are undergoing practical trial. Other work in the plating section includes fundamental research on the mechanism of the levelling action of some electroplating solutions, and work to produce on zinc-base die castings finishes comparable with anodised finishes on aluminium alloys.

Detailed studies of the hot-dip galvanising process—in which the effect of composition of the bath, time of immersion, rate of withdrawal, etc., have been investigated—have enabled recommendations to be made to the galvanising industry on methods of operating the process which ensure a uniform coating of zinc with the minimum attack on the basis steel, and which ensure the attainment of the highest technical efficiency.



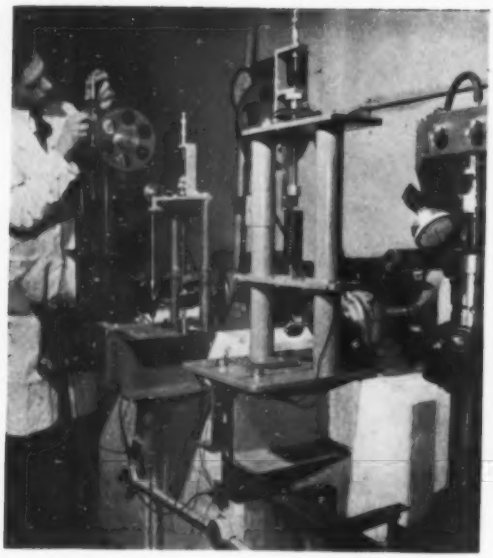
May jet test apparatus in which a fast-flowing stream of sea-water containing entangled air bubbles impinges on test specimens submerged in a tank of sea-water.

Aluminium-magnesium alloys, otherwise suitable for deep pressing, share with steel the ability to form stretcher-strain markings. An investigation of the problem has resulted in the satisfactory testing on a production scale of rolling schedules and heat treatment procedures by which such material can be supplied to the press shop free from this tendency.

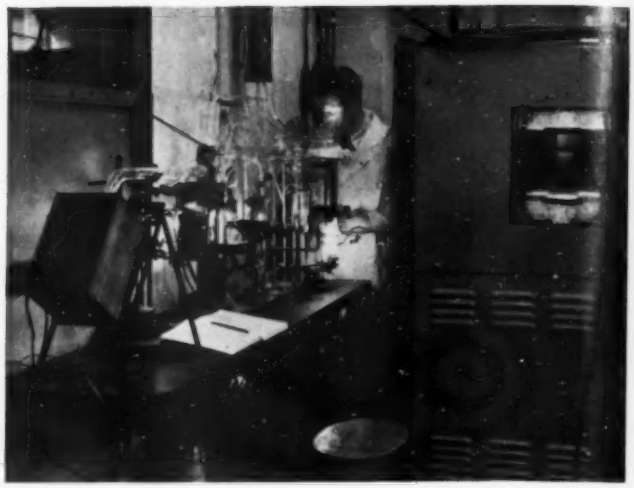
A study of the effects of additions of titanium and boron on the grain refinement of aluminium alloys has resulted in economies in the use of these materials, and has led directly to similar methods for the grain refinement of copper alloy castings. Other researches concerned with the improvement of processes include work on refractory linings for low-frequency induction furnaces melting copper and copper-rich alloys; the use of a hot impact tensile test for assessing the hot working properties of alloys; and the determination of the solubility of copper and lead in the slags occurring in their extraction and refining.

New Methods

Various methods of production of raw metal by wet processes starting with ore or scrap are being developed in North America, and it seems possible that nickel and copper could become available in large quantities in powder form. The industrial future of these methods will depend largely on the economic and technical value of the procedures available for converting the powders into semi-finished products. The Association has put in hand an exploratory research on the rolling of thin copper strip direct from powder, in order to provide some basis for assessing the probable value of such a process, and the problems which the direct production of semi-finished products from powder is likely to involve. In the experimental set-up, the powder is simply poured into the gap between a pair of rotating rolls and compacted into a strip strong enough to be handled. After heating and further rolling, the strength of the strip is



Machines for the accelerated assessment of fatigue resistance: the centre one is suitable for lead alloys and the others for stronger metals.



In this apparatus for determining the amount of oxygen in titanium, high frequency currents are used to melt a bath of steel in which the titanium is dissolved.

similar to that obtained from metal rolled from a cast ingot.

Shell moulding is a new approach in the foundry which enables castings to be made with greater precision, using a mould made from a mixture of sand and resin. The Association, in collaboration with a group of its members, has trained a man specially to assist industry in exploiting the process. A survey revealed the need for research on a number of problems, and a small hand-operated shell moulding machine has been built for the purpose. Points being investigated include the relative strength of different resin-sand mixes; sand reclamation; the running and gating of castings; dimensional accuracy; and the avoidance of distortion of shells during casting. Alternativem oulding materials to sand are also being considered.

New Materials

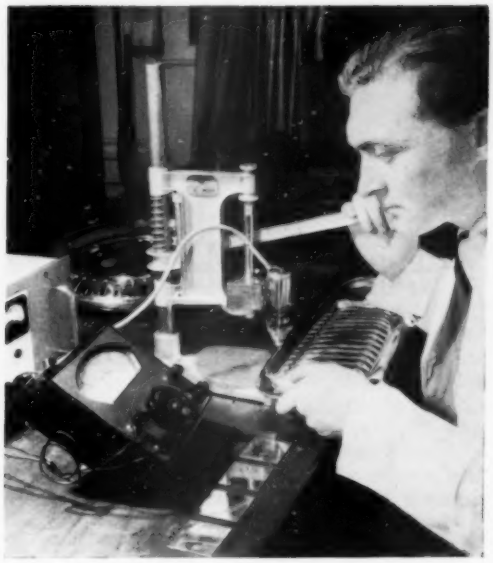
The demands of the gas turbine have led to considerable material developments in the last 15 or 20 years, and two parts of the engine for which the Association has carried out work on materials are the compressor and the heat exchanger. At the lower temperatures involved in the compressor, aluminium alloys are still used, but for the high temperature stages of compression the Association has studied firstly, aluminium bronzes and later, titanium alloys. Service in heat exchangers requires a certain degree of creep resistance and, particularly, resistance to corrosion by the products of combustion. Corrosion resistance in these circumstances has been shown to depend largely on composition, but the combination of operating conditions, both at temperature and when shut down, is complicated, and this particular picture is not yet completed.

The troubles with condenser tubes which were such a feature in warships in World War I had completely vanished in World War II as a result of research to which the Association has made a major contribution. Condenser tubes are made from corrosion resistant copper alloys, and suffer from "impingement" attack —the result of impingement on the tubes of air bubbles entangled in the stream of sea water used for cooling the condensers. Impingement attack causes deep craters in the tube and eventual perforation of the wall. The development of the May jet test, simulating these service conditions, enabled the behaviour of different alloys to be readily assessed and resistant materials developed.

The aluminium brass condenser tube developed by the Association and widely adopted with conspicuous success by navies, merchant fleets and power stations throughout the world, is so well known as to need no further emphasis: the same can be said of the iron-bearing cupro-nickels. An extension of the work which demonstrated the value of up to about 1% of iron in 70 : 30 cupro-nickel resulted in the development of low nickel iron-bearing alloys containing 5–10% nickel and 1–2% iron, which have great advantages over copper for sea water carrying pipes. Now the emphasis of the work has been switched to the difficulties encountered in operating condensers using heavily polluted estuarine cooling water, in which the presence of hydrogen sulphide—the result of bacterial action on sewage effluents —is a potent factor in accelerating the corrosion of these tube materials.

Not until the last few years had it been possible to produce titanium on anything like a commercial scale, and, although it is still an expensive metal, the Association is developing titanium alloys suitable for parts of gas turbine compressors. These alloys are being considered for use in this field because they have the advantage of lightness coupled with high strength at temperatures up to dull red heat, although their properties at still higher temperatures are disappointing. Because of the difficulty of melting titanium without taking up harmful impurities, special equipment has been devised and built for this purpose. High temperature creep tests and stress-rupture-time tests on experimental alloys are in progress in the mechanical testing section.

Columns of ion-exchange resins which are used for simplifying metallurgical analysis.



B.N.F. coating gauge for the measurement of the thickness of electroplated coatings by a thermo-electric method.

The use of aluminium in plumbing systems has for long been thought impracticable because of its liability to pitting, but recent work has suggested that protective coatings on the aluminium may be sufficiently long-lived to bring aluminium into the picture as a material which can be used in some plumbing systems. Meanwhile the search for lead alloys combining the required degree of resistance to fatigue and creep with stability of structure and the other desirable characteristics of cable sheathing and water pipe materials still continues, and some promising materials are in the development stage at the moment. Another plumbing item which has received attention is the galvanised tank, and it has been shown that minute amounts of copper dissolved from copper or copper alloy components can have a serious effect on the life of the tank by deposition on the zinc surface and the formation of local corrosion cells.

Testing and Control

Work of the types described calls for new methods of laboratory testing, and for the development of testing methods for use in production control. Under these headings particular mention may be made of such matters as the reduced pressure test for controlling the gas content of molten metal prior to casting; the rotating-load fatigue testing machine, which is much more suitable for fatigue testing at high temperatures than is a test in which the specimen itself rotates; and the newly-developed accelerated test for fatigue resistance. This last development enables an assessment of the endurance limit of a material to be made in a matter of 24 hours compared with several weeks by conventional methods. It is thus very suitable for work on the development of new alloys.

Methods of corrosion testing which have proved immensely valuable are the jet test associated with the name of R. May, and the atmospheric exposure test in which sulphur dioxide is used as an accelerator. This is a modification of the test originally developed by the Chemical Research Laboratory and now provides constant sulphur dioxide content and humidity. This test is at present being used in the nickel and chromium plating investigation referred to earlier.

Before the war the B.N.F. jet test was developed for the purpose of determining the thickness of electroplated deposits. Unfortunately the jet test is a destructive one, and, as far as nickel coatings are concerned, it depends to a large extent on the type of nickel solution used, and is thus not a particularly accurate means for routine inspection control. Recently the Association has developed a thermo-electric thickness gauge for this purpose, which has given satisfactory results for the determination of coatings of nickel with or without chromium. A small probe is applied to the surface for a few seconds and the thickness of the electroplating is then read straight away from a meter.

Spectrographic analysis of metals using solid electrodes has been an important item in the Association's programme since the early days, and the Association's pioneer work in this field has done a great deal to encourage and facilitate the use of this time-saving and in some cases more accurate analytical procedure. In recent years the Association acquired the first production control Quantometer designed for the analysis of copper and copper base alloys, although this instrument had earlier been developed for aluminium alloys. With the aid of the Quantometer new methods have been developed for the analysis of those copper base alloys which had previously proved difficult by spectrographic methods. The Association's main contribution in the spectrographic field has, in fact, been the development of analytical methods rather than of instruments, and much importance is attached to the use of solution methods to which a great deal of attention has been given in recent years.

Methods using ion-exchange resins are now in use in the chemical laboratory for simplifying metallurgical analysis. Metals can be separated from solutions merely by running them through columns of the appropriate ion-exchange resins. Washing the columns with other liquids allows the metals to be extracted from the resins

for estimation. An ion exchange column has been made for the preparation of pure water for laboratory use, replacing the electric stills.

Sufficient has been said in the foregoing to indicate the important part the B.N.F.M.R.A. has played in non-ferrous technical progress, particularly in the last 25 years, and there is no doubt that this progress will continue in the future to an increasing extent.

Morag Mhor in the Solent

Welded Aluminium Yacht on Show to Shipbuilders

ALUMINIUM alloys have interested the naval architect and have been used for boatbuilding since the earliest days in the history of the production of aluminium. Boats were built in this country of these alloys at the end of the 19th Century, but in those days little was known of the corrosion resistance of aluminium alloys in salt water, so that these first hulls had a very short life.

Experience was soon gained in using this new metal and ultimately sea water resisting alloys were developed. In these the main alloying constituent was magnesium, and a milestone in the use of aluminium was reached when *Diana II* was built. She was launched in 1931, and today, after twenty-four years of active service, her hull is still in excellent condition. She is a twin-screw motor cruiser, 55 ft. in length, and her hull and deckhouse are of riveted construction. Since *Diana II* was completed, many yacht hulls and workboats have been built of aluminium, whilst in larger shipbuilding aluminium has been used for deckhouses and superstructures.

Most of these structures were riveted because no welding process really suitable for industrial work was available. In this respect aluminium shipbuilding was not so highly developed as steel building. The cost of fabrication by riveting was an unfavourable factor in the economical justification for the use of aluminium, and this method of construction, demanding overlapping plate joints or butt straps, together with the use of flanges on angle bars, increased the first cost of the metal. The introduction of the self-adjusting arc process for welding aluminium was widely welcomed by the industry, since it appeared to offer promise as a process which could be almost as versatile for aluminium welding as the metal arc process commonly used for mild steel.

The British Aluminium Co., Ltd., has taken the lead in this country in the application of the self-adjusting arc welding process in shipbuilding. To demonstrate the suitability of the equipment under workshop conditions for practical aluminium shipbuilding, they commissioned the construction of the twin-screw auxiliary motor yacht *Morag Mhor*, with all-welded hull and masts. The yacht was designed by Laurent Giles & Partners, Ltd., in conjunction with the design staff of the builders, Saunders-Roe (Anglesey), Ltd., and the Development Department and Research Laboratories of The British Aluminium Co., Ltd.

Morag Mhor is 72 ft. 3 in. in length overall, and has a beam of 16 ft. with a draught of 7 ft. The displacement is 45 tons. She has an auxiliary ketch rig and is powered with two Gleniffer 72 b.h.p. DB.6 engines. The choice of scantlings for the hull involved consideration of the thicknesses of plating likely to be used in other aluminium welded construction, both in naval and merchant shipbuilding, and was tempered by a consideration of the lower limiting thickness of plating which could be successfully welded by the arc process.

The yacht was completed in the late summer last year, and after extensive trials in Scottish waters she was brought to the Solent in time for the Aluminium Centenary Exhibition, for showing to shipbuilders there, prior to leaving for a tour of shipyards in Holland and Belgium.

European Federation of Corrosion

AN important advance towards closer European co-operation in the field of science and technology was made two years ago by the creation of the European Federation of Chemical Engineers. A further step towards this goal has just been taken.

The European Federation of Corrosion was formed on May 19th, 1955, on the occasion of the Convention of Chemical Technology in Frankfort-on-the-Main, when 33 technical and scientific societies from eight European countries (Germany, France, Italy, Luxembourg, Austria, Sweden, Switzerland, Spain) met to discuss the phenomena and causes of corrosion. Norwegian and Spanish societies, which were unable to be represented at these meetings also declared their willingness to collaborate. The object of the new Federation is to foster European collaboration in the field of research on the means of combating and protecting materials, for the benefit of all concerned.

Beryllium Copper Moulds

Extensive Use in U.S. Plastics Industry

With its high hardness and good thermal conductivity, beryllium copper is a suitable material for moulds used in the plastics industry. Brief particulars are given of a hobbing-casting technique for their production.

BERYLLIUM copper moulds have effected important cost-savings in the United States plastics industry, and are extensively used in the injection moulding of many industrial and novelty parts. As a cavity material, beryllium copper has a number of useful properties. By a precipitation hardening treatment, hardness values of 40 Rockwell C can be achieved, and new alloys capable of being hardened to 50 Rockwell C are being developed. Moreover, the alloy is quite tough and does not tend to chip or crack. The high hardness is coupled with good thermal conductivity, which helps to improve production rates.

Satisfactory moulds can be produced by three techniques : (*a*) sand casting ; (*b*) investment casting ; and (*c*) pouring the molten metal round a master hob and applying pressure as the metal solidifies. Sand cast moulds are used for large cavities or forces exceeding 50 lb., or where few castings are required. Pressure cast moulds, however, prove more economical in many applications because there are fewer finishing operations. The details of the master hob are accurately reproduced, the structure is unusually dense, and the excellent surface finish needs no more than liquid honing.

Merits of Pressure-Cast Beryllium Copper

Advantages of pressure cast beryllium copper moulds include :—

(1) Low initial cost through the elimination of the expensive machining necessary in steel cavities where hobbing is not practical.
(2) Since cavities are produced from master hobs, multiple cavities of exact likeness are readily produced at low cost.
(3) Sound castings, free from porosity, mean good properties as measured by high compressive strength and hardness.
(4) A thermal conductivity 2¼ times that of steel gives substantially increased production rates.
(5) Cavities can be chromium plated when necessary to prevent corrosion by certain plastics.
(6) Raised sections, including lettering, can be pressure cast with beryllium copper, whereas steel cavities require machined inserts.
(7) "As-cast" tolerances for pressure castings can be held to plus or minus 0·004 in./in.

These same advantages are also of significance to the die caster, since they offer reduced tooling costs in the preparation of short-run dies.

Best results have been obtained through the use of a 2·7% beryllium-content alloy as a mould material. The molten beryllium copper at 1,100° C. is poured into a steel cavity, and pressure applied before the metal freezes. Hydraulic presses of 20 to 200 tons capacity will supply the required pressures, ranging from 2,000 to 10,000 lb./sq. in., depending on the size and shape of the hob. After removal from the press, the castings are solution-annealed 1 to 3 hours (depending upon section thickness) at 730° C., followed by an immediate water or oil quench. Cavities are then liquid honed prior to the hardening heat treatment of 3 hours at 315° C.

Casting Procedure

During casting the hob is supported on the chase plate of the lower platen of the press, and the molten beryllium copper is poured over the hob : a plug supplies the pressure to the molten metal from the top through the upper press platen. The pressure is applied as rapidly as possible in order to compress the beryllium copper before it solidifies. The pouring temperature for beryllium copper depends upon the quantity handled, but it usually averages 1,050–1,100° C.

Before being placed in position on the press, the hob and shim plates are heated to 650° C. in a soaking furnace. It is frequently necessary to provide a roller conveyor between the soaking furnace and the press in order that the hob can be rapidly rolled into position. The metal is poured as soon as the hob and plates are in position on the press bed. Pressure is applied as rapidly as possible, and all operations should be performed quickly to prevent freezing of the metal before the pressure is applied. If freezing occurs before the pressure is applied, a bad casting will result.

The platen should rise at a speed of not less than 0·2 in./sec. As a general rule 2,000 lb./sq. in. will result in a good casting, but the final decision on pressure will depend on the size and shape of the hob. A large hob may require 10,000 lb./sq. in., whereas a hob with thin sections must be lightly pressed, or the thin sections move and distort the cavity.

Reports say that the alloy Berylco 275C has given very good results in the manufacture of moulds by this process. The nominal composition of this alloy is : beryllium 2·75% and cobalt 0·50%, with the remainder copper. Another casting alloy is Berylco 20C, which contains 2·0% beryllium and 0·5% cobalt.

Some work has been done in hobbing a beryllium copper mould in a manner similar to that used with steel. The procedure of die hobbing consists of sinking a properly hardened, highly polished steel master of the article to be cast into a piece of soft metal by means of a hydraulic press. Soft beryllium copper can be hobbed with either a steel or hardened beryllium copper hob. Intermediate annealing is required for relatively deep or intricate cavities.

Investment Casting

Normal investment casting practice is followed in the production of moulds in beryllium copper, the steps preceding the pouring operation being: (1) wax patterns are formed in steel or soft metal dies; (2) wax gates are attached and patterns are assembled in a cluster; (3) the assembly is then invested and the investment permitted to harden; and, finally, (4) heat is used to remove the wax pattern and bake the mould, and the cavity is then ready to be poured.

Either induction-heated or gas-fired crucibles can be used for preparing the melt. Beryllium copper is generally available in 3 oz. and 2½ and 5 lb. pigs. The 3 oz. pigs are especially convenient, since they facilitate handling in small batch melting. The charge should be melted as rapidly as possible to minimise loss of beryllium and gas absorption. Fluxes or slag covers are generally not necessary.

A pouring temperature should be selected that will permit good feeding to ensure sound castings. Past experience indicates that temperatures in the range 1,050–1,130° C. give good results. Increased fluidity for light sections can be obtained with temperatures at the upper end of this range. Whenever possible, centrifugal castings should be used, since this method excludes dross and gas, and produces sounder and denser castings than gravity pouring methods.

Oxygen Flash Smelting of Copper Sulphide Concentrates

International Nickel Plant in Full Operation

THE International Nickel Co. of Canada, Ltd., which has pioneered many notable advances in extractive metallurgy, has given details of its oxygen flash smelting process for treating copper concentrates. One of the world's first commercially successful processes for smelting fine sulphides in suspension, the method developed by Inco is now being used to treat all of its copper sulphide concentrates. The company in 1954 delivered more than 250,000,000 lb. of refined copper.

Under development since 1945, the process recently completed its first full year of successful operation. It has reduced Inco's copper smelting costs and, in addition, the use of oxygen for smelting has resulted in the production of a high quality furnace gas from which liquid sulphur dioxide and sulphuric acid are made.

Details of the process were outlined in a paper prepared by the staff of International Nickel's Mining and Smelting Division at Copper Cliff, Ontario, and presented recently at the annual meeting of The Canadian Institute of Mining and Metallurgy by C. E. Young, of the smelter operating staff.

Development of the new process involved the co-operative efforts of the International Nickel Company, Canadian Industries (1954) Ltd., and the Canadian Liquid Air Co., Ltd. The process eliminates the fuel normally required for smelting and permits large-scale output by Canadian Industries (1954), Ltd., of liquid sulphur dioxide produced from the flash smelting furnace gases. The low-cost oxygen which makes Inco's process economically possible is produced by a tonnage oxygen unit known as an Oxyton, which was built for Inco by Canadian Liquid Air Co., Ltd. This unit produces 325 tons of 95% pure oxygen every 24 hours, corresponding to 2⅜ billion cubic feet of oxygen per year, or three times the production of all the cylinder oxygen plants in Canada.

The conventional treatment of copper sulphide concentrate involves smelting in reverberatory furnaces with pulverised coal or other fuel, with or without prior roasting. The matte formed contains a large proportion of iron sulphide, which is subsequently removed by oxidation and slagging in Bessemer converters. The converter slag thus formed is returned to the copper reverberatory furnaces. The copper sulphide remaining is "blown" to blister copper, which is then refined for commercial use. At Inco, the former practice was to wet charge the copper concentrates with flux to reverberatory furnaces, and smelt with pulverised coal.

In the Inco flash smelting process, finely divided copper concentrates and flux are dried and injected with oxygen into the pre-heated smelting furnace to produce matte, slag and a gas containing about 75% sulphur dioxide. In the furnace, the oxygen combines with some of the sulphur and iron of the chalcopyrite (copper-iron-sulphide) to form sulphur dioxide and iron oxide. The heat of the reaction is sufficient to melt the residual copper-iron sulphide to form a matte, and the iron oxide combines with the siliceous flux to form a slag. An important feature of the Inco process is a novel method of cleaning the copper-rich slag by flash smelting pyrrhotite at the skimming end of the furnace. The slag is showered with iron sulphide droplets which, in settling into the matte beneath, extract copper from the slag.

The flash smelting furnace gas is water-scrubbed and treated by a wet Cottrell plant before it is converted into liquid sulphur dioxide by Canadian Industries (1954) Ltd. The production of liquid sulphur dioxide involves drying the cleaned gas with sulphuric acid, then compressing and cooling the gas to condense the sulphur dioxide. Using gas from this furnace and other smelter units, Canadian Industries (1954), Ltd., last year produced approximately 70,000 tons of liquid sulphur dioxide for use by the Canadian sulphite pulp industry, as well as about 65,000 tons of 100% sulphuric acid.

Inco's flash smelting furnace is 68 ft. long, 24 ft. wide and 17 ft. high at the ends, outside its steel casing. It has a smelting capacity of approximately 1,000 tons of dry solid charge daily.

Iron and Steel Scrap Prices

THE Minister of Supply, after consultation with the Iron and Steel Board, has made an Order increasing the controlled prices of iron and steel scrap to allow for the rise in rail freight charges which took effect on June 5th. The increases range from 6d. per ton to 3s. 3d. per ton. The Order, the Iron and Steel Scrap (Amendment No. 2) Order, 1955 (Statutory Instrument 1955, No. 799) came into effect on June 8th, 1955. Copies are on sale at H.M. Stationery Office.

New Heat Treatment Plant For Old-Established Firm

General view of the new heat treatment shop.

A NEW heat treatment division of Uddeholm, Ltd., a subsidiary of one of Sweden's largest and most famous enterprises, was opened by the Lord Mayor at the Company's Crown Works in Birmingham recently.

The Uddeholm concern owns, besides extensive forest lands and sizeable farmlands, the most important parts of the Värmland mining district, the iron ore fields at Taberg, Nordmark and Finnmossen, and also Persberg and Långban, which are both closely connected with Uddeholm. Industry has been developed in the area since the end of the 17th century—based on forests, ore and water power—and today the Company's main components are the iron and steel works at Hagfors, Nykroppa and Degerfors, the cold rolling mills at Munkfors, Storfors, with its tube mill, and Blombacka, where wire and wire ropes are made. The company is also active in the field of wood processing.

History of the Company

The head office at Uddeholm is situated in a lovely quiet countryside where there is no trace of industry—an unusual location which is the result of historical circumstances. Considerable tracts of land in the district around Lake Råda came into the hands of noblemen at a fairly early period, and one of them, a governor of the province named Harald Posse, built a farm there in the middle of the 17th century, which he called Uddeholm.

Seeing the possibilities offered by the neighbourhood, he contracted in 1668 with Johan Karlström to build a blast furnace and forge somewhat higher up the valley. Some years later Karlström bought the property, but the early years were fraught with economic difficulties, and it was not until the middle of the 18th century, when the leadership of the Uddeholm works was in the capable hands of Bengt Gustav Geijer, one of the most influential pioneers in Swedish industry, that the enterprise began to flourish. New works were built in the vicinity, which were combined in 1746 into a kind of family-owned company. This enterprise was converted into modern company form in 1870, when Uddeholms AB came into being.

Modern steel-making methods were being introduced at the time and the need for centralising production became apparent. Starting in the middle '70's, an entirely new steelworks was, therefore, built at Hagfors, where water power was available. The remainder of the production was also concentrated in a comparatively few works, among them Munkfors, where the first forge had been operating as early as 1670, and which had been acquired by the company in 1829.

The small furnaces and forges were gradually closed down, and in their place Storfors Bruk AB, with Nykroppa Järnverk and Storfors Rörverk, became part of the Uddeholm concern in 1918. Blombacka and Degerfors were taken over in 1929 and 1939, respectively. In 1953, the newest of the Uddeholm works on the steel manufacturing side went into operation at Perberg for the production of sponge iron for use in the Company's steelworks.

Uddeholms AB produces annually some 180,000 tons of steel in the form of hot rolled and forged products, tubes, castings, cold rolled strip, and wire and cable. Included in these products are a number of special steels, such as those used in tool making, which are comparatively expensive, and whose optimum properties are achieved by careful heat treatment. In order to make available to customers facilities for such heat treatment, a new division has been formed by Uddeholm, Ltd., and a heat treatment plant established at Crown Works.

The Heat Treatment Plant

A bright, clean, and well illuminated shop has been equipped to undertake the complete heat treatment of the full range of carbon steels, in the form of hot and cold working tools including punches, blanking and drawing dies, as well as moulds for plastics and other intricate work. In this shop, the division has all the diverse process heating equipment necessary for modern heat treatment techniques and the speedy handling of orders. In keeping with Uddeholm's policy, the installation is made up of several small furnaces and ancillary equipment, allowing the employment of small easily handled charges with resultant constant expert supervision through all stages of treatment. There are eight

37·5 kW salt bath providing temperatures up to 1,350° C. to meet the requirements for hardening high speed steels and certain hot die steels.

Part of the furnace installation for the heat treatment of tools and dies showing salt baths and one of the oil quench tanks. The salt bath in the foreground has a calorised mild steel pot and can be used for cyaniding.

separate and independently controlled furnaces of four distinct types, four quench tanks providing oil and water quenching, and a low temperature oven, all of which, together with other electrical apparatus such as lighting, ventilation and sub-station equipment, were supplied by The General Electric Co., Ltd.

Preheating Equipment

The heat treatment of tools commences with preheating, generally to a temperature of up to 700° C., prior to treatment in salt baths. For this preheating, the shop is equipped with two forced air circulation furnaces with loadings of 20 kW. and 30 kW., respectively. In both furnaces rapid heating is combined with a high degree of accuracy. The smaller furnace employs a charge carrying basket 20 in. diameter and 18 in. deep, whilst the larger has a basket 20 in. diameter and 30 in. deep; to allow air circulation round the tools, these baskets have perforated bottom plates. Vigorous air circulation, provided by a centrifugal fan, ensures utmost uniformity of temperature throughout the charge and makes possible precise control of the low temperatures used. In each furnace the heating chamber is enclosed by a cylindrical baffle, which shields the charge from direct heat radiation and confines the air flow to a path over the elements and round the charge. To prevent loss of heat due to the intake or escape of air, the chamber is effectively sealed by an easily operated lift and swing lid. Automatic temperature control is provided for both furnaces. Besides preheating tools, the furnaces can be used for initial tempering immediately after hardening.

Hardening of Tools and Dies

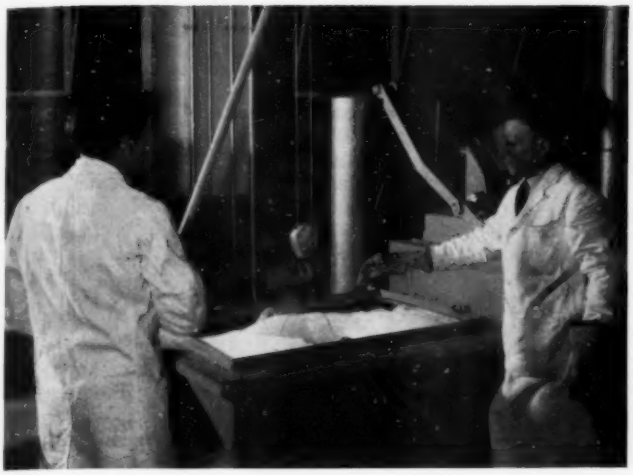
Three electrode salt baths provide a range of operating temperatures for the hardening of tools and dies, and ensure rapid and uniform heating whilst providing protection from scaling and decarburisation. A 37·5 kW. salt bath operates at temperatures up to 1,350° C., meeting the requirements for hardening high speed steels and certain hot die steels. The bath has an inner refractory lining backed by heat insulating brickwork, and its usable dimensions are 8 in. diameter by 14 in. deep. To measure the bath temperature, a radiation type pyrometer is used in conjunction with a thermo-electric controller.

Two baths, each of 36 kW. rating, are used for the bright hardening of tool steels. One, with a ceramic pot 12 in. diameter and 16 in. deep, operates at temperatures up to 1,000° C., the other provides temperatures up to 950° C. This latter has a calorised mild steel pot, 12 in. in diameter and 16 in. deep, and can be used for cyaniding. Both furnaces have automatic temperature controllers, the temperatures being measured by immersed pyrometers.

In addition to the baths already mentioned, there are two 15 kW. rectangular salt baths, with effective dimensions of 20 in. × 25 in. × 24 in., heated by immersion elements. One of these provides temperatures up to 350° C. and is used for martempering tool steels to reduce risks of cracking and distortion. The other can operate at temperatures up to 600° C., and is suitable for the secondary hardening of high speed and hot die steels. In both baths the molten salt is kept in circulation by an easily removable electrically driven stirring paddle. They can be cooled after the insertion of a hot charge by a forced air flow passing between the furnace lining and the insulating brickwork. The baths are complete with automatic temperature control gear.

Hardening, Pack Carburising and Annealing Large Tools

A 30 kW. horizontal batch furnace is installed for hardening and pack carburising of tools which are too large for salt bath treatment, and for annealing. The furnace chamber, which is 15 in. high, 24 in. wide and 36 in. long, is heated by nickel-chrome wire in coil form arranged in the side walls, the roof, and the hearth, to



Quenching in a solution of 5% caustic soda.

provide temperatures up to 1,100° C. To facilitate the moving of charges in and out of the furnace, a specially designed trolley can be locked in position against the furnace mouth and provides a firm work table at the same level as the furnace hearth. A grid forms the table surface so that work removed from the carburising box rests on the grid while the carburising medium falls through into a receptacle. This residue can then easily be cleared by removing a panel on the trolley front.

Oil and Water Quenching

For water quenching, one 400- and one 200-gal. tank containing 5% caustic soda solution are used. To prevent stratification, the solution is kept in circulation by being pumped from the top and returned to the bottom. Oil quench tanks of 450- and 300-gal. capacity contain immersion heaters to raise the oil to the normal quenching temperature of 40–50° C.; an electrically driven paddle stirrer maintains circulation of the oil. Provision for cooling the quenching medium by means of immersed water-carrying coils is provided on all the quench tanks. Tools can be quenched individually or in baskets. Oil to be discarded after quenching is piped direct from the tanks to a burner, where it is combined with fuel oil and used for central heating.

Selective Tempering of Tools

To ensure that all work is double tempered, a forced air circulation oven giving a maximum operating temperature of 400° C. is used for the selective tempering of tools after hardening. The oven has a loading space 24 in. high × 15 in. wide × 18 in. deep, and contains three perforated shelves. It is of double-cased construction, the elements of nickel-chrome wire on porcelain formers being mounted on the inner casing behind a baffle. This baffle guides the air flow along a path down the oven sides over the elements, and up through the oven chamber.

Inspection and Control

Sufficient has already been said to show that the heat treatment is carried out under laboratory conditions of control, after which the work is finally inspected and hardness tested. Uddeholm have always been to the forefront of hardness testing and it is of interest to record that the famous Bergsman micro-hardness tester was developed in the Munkfors laboratories.

Pack carburising in a 30 kW horizontal batch furnace.

Stocks

A modern warehouse, under the same roof as the heat treatment shop, enables the Company to offer a comprehensive stock of the full range of tool steels, comprising straight carbon steels, oil hardening steels, high carbon, high chrome steels and high speed steels.

Birthday Honours List

continued from page 2

D.G. Ball, Chief Inspector, Kirkstall Forge Engineering, Ltd.
F. W. Barlow, Foreman, Morris Motors, Ltd., Coventry.
B. Boam, Brickmaker, Butterley Company, Ltd.
P. W. Charles, General Foreman, De Havilland Engine Company, Ltd.
E. S. Cook, Works Superintendent, Johnson & Phillips, Ltd.
W. Earl, Operating Assistant, Shell Petroleum Company, Ltd.
W. Fairhurst, Foreman, Electronic Tubes, Ltd.
A. S. W. Fenwick, Head Foreman Shipwright, J. I. Thornycroft, Ltd.
J. Morrison, Head Foreman Plumber, Harland and Wolff, Ltd., Belfast.
F. Prime, Driller, Yarrow and Company, Ltd.
W. Richardson, Senior Blacksmith, Birtley Company, Ltd.
W. H. Shacklady, Tank Wagon Driver, Esso Petroleum Company Ltd.
J. W. Webb, Superintendent of Ambulance Room, Firth Vickers Stainless Steels, Ltd.

International Metallurgical Meeting

LONDON was the scene of two international metallurgical gatherings last month—the Joint Metallurgical Societies Meeting in Europe at the beginning of the month, and the International Foundry Congress from the 19th to the 25th. The former was the outcome of the acceptance by the American Institute of Mining and Metallurgical Engineers and the American Society for Metals of invitations, from the Iron and Steel Institute, the Institute of Metals, and the leading metallurgical societies in Germany, Belgium, France and Sweden, to send representatives to a joint meeting in Europe. The meeting opened in London on June 1st with 180 delegates from the U.S.A. and more than 150 from the Continent. A registration of British participants in the neighbourhood of 300 was undoubtedly reduced somewhat, owing to the difficult travelling conditions resulting from the rail strike.

Inaugural Meeting

The opening plenary session was held in the Assembly Hall, Church House, Westminster in the afternoon of June 1st, when the Chairman, Sir Charles Bruce Gardner, Bt., President of the Iron and Steel Institute, prefaced his welcome to overseas visitors by reading a message of greeting sent to him by H.R.H. The Duke of Edinburgh, Patron of the Meeting. Sir Charles was supported in his welcome by Dr. Maurice Cook, President of the Institute of Metals. Responses were made by Dr. C. E. Williams, a Past President of the American Institute of Mining and Metallurgical Engineers, in the absence of the President, Mr. H. de Witt Smith, and by Dr. G. A. Roberts, President of the American Society for Metals

At the invitation of the Chairman, the Hon. R. G. Lyttelton, Past President of the Iron and Steel Institute, presented to Professor John Chipman, Head of the Department of Metallurgy, Massachusetts Institute of Technology, the Bessemer Gold Medal of the Institute for 1955, which had been awarded to him in recognition of his distinguished contributions to knowledge of the physical chemistry of steelmaking.

To mark the occasion, Mr. H. de Witt Smith and Dr. G. A. Roberts were nominated to Honorary Life Membership of the Institute of Metals, and Dr. Howard Biers, a member of the American Committee, Mr. W. H. Eisenman, for the past 37 years Secretary to the American Society for Metals, and Mr. E. O. Kirkendall, Secretary of the American Institution of Mining and Metallurgical Engineers, to Honorary Membership of the Iron and Steel Institute.

In return, Sir Charles Bruce-Gardner, Dr. Maurice Cook, Mr. K. Headlam-Morley, Secretary of the Iron and Steel Institute, and Lt.-Col. S. C. Guillan, T. D., Secretary of the Institute of Metals, were made Honorary Life Members of the two American Societies.

Following the business meeting, Sir Lawrence Bragg, O.B.E., M.C., F.R.S., Fullerian Professor of Chemistry, and Director of the Davy-Faraday Laboratory at the Royal Institution, delivered the inaugural lecture of the meeting on "X-ray Analysis and the Structure of Metals".

A group of delegates at A.V.P. Paramount Foundries

Technical Sessions

The wide variety of interests represented by the participants in the meeting was reflected in the fact that there were six simultaneous discussions proceeding at each session. In the morning of Thursday, June 2nd, the topics were : blast furnace practice ; steelmaking—basic open hearth furnace design and operation ; melting and casting of non-ferrous metals ; continuous casting ; high temperature alloys ; and education and training. In the afternoon the discussions were focused on : iron and steelmaking—desulphurising and desiliconising ; steelmaking—the role of the electric arc furnace in tonnage steel production ; production of steel strip and sheet ; problems of high speed wire drawing ; rate processes in metallurgy ; and heat treatment of special alloys. The technical sessions concluded on Friday, June 3rd, with morning discussions on ; physical chemistry of steelmaking ; production of steel ingots of high quality ; production of metals of high purity ; extrusion of ferrous and non-ferrous metals ; fracture of metals ; and heat treatment of forgings.

Social Functions and Works Visits

Overseas visitors attended a Government reception on the Wednesday evening, and at a Guildhall banquet on Thursday, over 500 guests of the British Iron and Steel Federation heard speeches from Mr. A. G. Stewart, President of the Federation ; Alderman Sir Seymour Howard, Lord Mayor of London ; Sir Charles Bruce-Gardner ; H. E. the American Ambassador Winthrop W. Aldrich ; Dr. Maurice Cook ; Dr. C. E. Williams ; and Dr. G. A. Roberts.

A number of sightseeing tours and technical visits in and around London were arranged for delegates and their ladies, in addition to tours of metallurgical areas which included South Wales, Birmingham, Sheffield and Scunthorpe, Durham and North Yorkshire, and Scotland. Unfortunately the rail strike made some of the tours difficult, and some works visits were altered or cancelled.

Experimental Light-Alloy Sledges

DETAILS have been announced of a revolutionary type of sledge—built in the shape of a punt and fabricated entirely from aluminium alloy—which was tested under actual working conditions by a British (Sherborne-Cambridge) Spitzbergen Expedition 1954. The idea of using aluminium sledges originated with the organiser of the expedition, Dr. G. T. Wright, of Marlborough College, and after discussions rough sketches of the sledges were made. No detail drawings were prepared, the sledges being hand-made by Elms Metals Ltd., using various aluminium alloys supplied by James Booth and Co. Ltd.

Three sledges were constructed—one 12 ft. long and two 8 ft. long—the main shells each being formed from a single sheet of 16 s.w.g. thick M.G.5 alloy, with edge stiffeners of $\frac{7}{8}$ in. × 18 s.w.g. M.G.5 tube and tying hooks from M.G.5 plate. Both stiffeners and hooks are welded to the main shells. The three sledges are each 2 ft. wide and 8 in. deep, and run on runners, 2 in. high and $2\frac{1}{2}$ in. deep, riveted to the main shell. The runners are constructed from Duralumin H extruded top-hat section.

A report on these experimental sledges has been made by a member of the expedition, Mr. L. S. Wilson (Emmanuel College, Cambridge), who says that they moved easily over pure ice and in the higher snow-fields of the glaciers, and that although the largest sledge carried a load of 500 lb. and each of the smaller ones, 300 lb., the runners rarely sank into the snow more than $\frac{1}{2}$ in. The report suggests that for soft snow it may be advisable to fit aluminium-alloy ski-runners on 6 in. pillars below the main shell.

One of the difficulties associated with camping in the Arctic or Antarctic is to obtain water, as melting snow or ice is a long process and also expensive in paraffin. It occurred to the expedition that the " boat " shape of the new sledges might make them suitable as water reservoirs and, each time the expedition camped in one place for any length of time, the sledges were filled with snow which the sun soon melted, through direct insolation and radiation from the aluminium. In recording this, the report says " The availability of water saved countless hours, and facilitated rapid starts." The report finally states " These experimental sledges were undoubtedly a great success and should be used increasingly in the future."

Exothermic Ferro-Chromium

EXOTHERMIC ferro-chromium, a special material for making additions of chromium to steel in the ladle, is now being produced commercially in this country by British Electro Metallurgical Company, a Division of Union Carbide, Ltd., at their Wincobank, Sheffield, plant. The Bemco material contains 55% to 57% chromium and a maximum of 4·5% carbon : it is supplied in the form of cylindrically shaped briquettes measuring approximately $1\frac{1}{2}$ in. high and 2 in. diameter.

A number of advantages are claimed for this material. Since the alloy is in the form of small uniformly sized briquettes, it has a high rate of solution in molten steel and yields consistently high chromium recoveries of over 90%, thus providing good control in meeting close chromium specifications. The high ratio of chromium to carbon results in a low carbon addition to the steel in the ladle, an increment of 1% chromium resulting in a maximum carbon addition of only 0·08%.

The material also has adequate exothermicity to prevent the excessive chilling that frequently results from the addition to steel in the ladle of large quantities of standard ferro alloys, such as high carbon ferro-chromium. The relatively low ignition temperature is a safeguard against accidental combustion.

Extensive field tests have been carried out at British steel works and of particular note were the preliminary trials with a Tropenas converter. These tests showed no drop in the temperature of the steel being treated ; a typical result was obtained when from a 30 cwt. ladle of 0·35–0·40% carbon non-alloyed steel, $5\frac{1}{2}$ cwt. were lip teemed into a small lip ladle in the bottom of which has been placed 10 lb. of exothermic ferro-chromium. There was no violent reaction, and although, some slag was formed, this was not in large quantity and did not cover more than one-third of the surface area.

Other 5 cwt. lip ladles of steel (not to be alloyed) were being taken from the same master ladle and it was possible to obtain a perfect comparison of thermal variations when using exothermic ferro-chromium. All the small ladles were at a high temperature before filling and those used for steel temperature investigations had previously contained molten steel from the same master ladle. The temperature in the master ladle was 1,540° C. and those in both the treated and untreated ladles were similar at 1,520° C. Thus the latent heat of fusion of the chromium alloy was fully satisfied by the exothermic reaction.

The composition of the base steel was 0·4% carbon and 0·16% chromium. Analyses of the treated steel showed 0·46% carbon and 0·99% chromium half way through, and, similarly, 0·46% carbon and 0·99% chromium at the end of the cast. A good fluid cast was obtained. The actual exothermic ferro-chromium used contained 4·4% carbon and 56·5% chromium. These results showed an increase of 0·83% chromium obtained from a theoretical 0·905% chromium addition, which is equal to a recovery of about 92%.

A further set of trials showed that with a chromium

addition of 1%, recoveries in three samples from one cast, drawn at the commencement, in the middle, and at the end of the cast, were about 90·3% of the chromium added. It is also interesting to note that at this particular trial the temperature drop between bath and ladle was 44° C. as against the normal drop (without any addition of ferro alloys in the ladle) of 51° C.

Later tests were carried out on a much large scale with a basic open hearth furnace, and results here were also remarkably successful. The high chromium recoveries and the maintenance of steel temperature in the ladle were comparable with the Tropenas trial findings. Chromium recoveries in the steel were over 90% of the added amounts. Furthermore it was found that no detrimental effects were experienced on the grain size of grain controlled steels.

New and Revised British Standards

HIGH PURITY ZINC, ZINC ALLOYS FOR DIE CASTING AND ZINC ALLOY DIE CASTINGS (B.S. 1003-4: 1955). PRICE 3s. EACH.

THESE revised British standards were originally issued in 1942, when the development of dependable zinc alloys of good mechanical properties had resulted in a rapid increase in the use of zinc alloy die castings for engineering purposes. These alloys are based on the result of much research, and the chemical compositions chosen were those giving the optimum balance of properties. Since subsequent experience has shown that some allowance should be made for the loss of aluminium and magnesium during casting, their limits have been slightly modified in this revision.

The presence in these alloys of certain impurities which are found in zinc ores, may cause liability to intercrystalline corrosion, with resultant dimensional instability and loss of strength. These impurities are, therefore, strictly limited in the basic zinc used for the manufacture of these alloys. Limits have also been included for other elements which were included in the previous edition under the heading "traces" and the same limits are included for the alloys. B.S. 1005 "Sampling and Analysis of High Purity Zinc and Zinc Alloys for Die Castings" and B.S. 1225 "Recommended Methods for Polarographic and Spectographic Analysis of High Purity Zinc and Zinc Alloys for Die Casting", will in the future be revised to include methods for the determination of these additional elements.

Arrangements have now been made for the use of the B.S.I. Certification Mark in connection with this standard. Manufacturers licensed by the B.S.I. to use this mark are required to ensure that the whole of their production of zinc alloy die castings complies with Part 2 of the standard.

GENERAL RECOMMENDATIONS FOR THE RADIOGRAPHIC EXAMINATION OF FUSION WELDED JOINTS IN THICKNESSES OF STEEL UP TO 2 in. (B.S. 2600: 1955). PRICE 4s.

THE work resulting in the recommendations made in this standard was undertaken at the request of the British Welding Research Association, the Committee having taken note of the work of the FE 6 Committee of that Association. The increasing use of X-rays and gamma rays for the examination of welded joints in a wide variety of constructions has made it desirable to issue some recommendations of a general character giving guidance on the application of these methods. The standard is divided into the following four sections:

Section 1: covers the general recommendations for all types of radiography within the scope of the standard.

Section 2: covers X-ray techniques for general application.

Section 3: covers X-ray techniques for special applications.

Section 4: covers gamma-ray techniques.

B.S. 2600 contains an appendix which amplifies the statements contained within the various clauses.

SOLID DRAWN COPPER ALLOY TUBES FOR THE MANUFACTURE OF SCREWED FERRULES AND COPPER ALLOY SCREWED FERRULES FOR CONDENSER, EVAPORATOR, HEATER AND COOLER TUBES. (B.S. 2579: 1955). PRICE 2s. 6d.

THIS new British standard supersedes that part of B.S. 378: 1941 which was omitted when the 1953 edition of that standard was published. B.S. 378: 1953 specified requirements for five alloys from which condenser tubes can be made. These same five alloys are included in this standard, for the manufacture of screwed ferrules and the ferrules themselves. Of these five alloys, two (70/30 brass and 70/29/1 (Admiralty mixture) brass) were included in the 1941 edition of B.S. 378. The three new alloys included are: aluminium brass, copper nickel, and aluminium bronze (7% aluminium).

ACCEPTANCE TESTS FOR SINTERED METAL POWDER COMPONENTS (B.S.2590: 1955). PRICE 3s.

THIS standard makes recommendations with regard to the sampling and testing of the finished sintered component as distinct from the metallic powder from which it is made, for which other British standards are in course of preparation. It also makes recommendations with regard to the test pieces to be used for mechanical testing, as the normal British standard test pieces designed for metal products are not suitable for the small components to which the recommendations of this standard apply.

CODE OF PRACTICE FOR ZINC ALLOY PRESSURE DIE CASTING FOR ENGINEERING (C.P. 3001: 1955). PRICE 5s.

THIS code, which has been prepared jointly with the Institution of Mechanical Engineers, has as its objective the establishment of recognized practices in the design, production and inspection of zinc alloy die castings, in order to ensure that the materials used, the procedures followed, and the design of the castings, shall provide a product that is reliable in every respect.

Pressure die casting in zinc alloy permits the very rapid production of engineering and allied components, and also intricacy of design. It has, therefore, obvious advantages when a component is required in large quantities. For engineering components however, mechanical properties and durability are important considerations, and for this reason the best features

of design should be employed and the optimum casting technique adopted.

Zinc alloy die castings will perform satisfactorily in service only if they are free from contamination by certain elements harmful to the mechanical properties and corrosion resistance. The code, therefore, states that it is essential that these elements should not be present in higher proportions than those indicated in B.S. 1004 "Zinc Alloys for Die Casting".

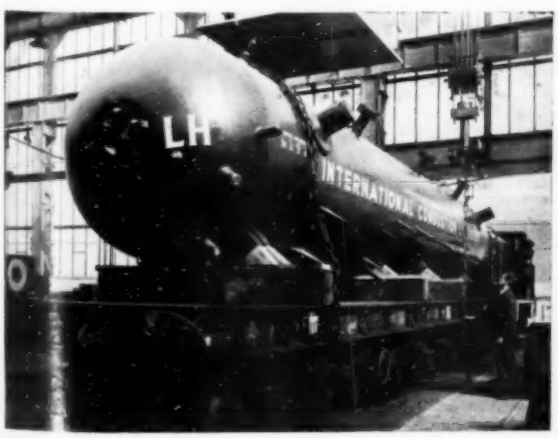
Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

Largest Hollow Forged Boiler Drum

The largest capacity hollowed forged boiler drum ever made as a one-piece forging left Sheffield by rail on Friday evening, 13th May, on its journey to the British Electricity Authority's new power station at Willington near Derby, where it will form part of the second 100 MW boiler unit to be installed in this country. It was made for International Combustion, Ltd., London and Derby, at the River Don Works of English Steel Corporation, Ltd., and weighs approximately 79 tons, 15 tons heavier than the previous record-breaking drums of this type, which were also E.S.C. products. Measuring 44 ft. from end to end, with walls $5\frac{3}{16}$ in. thick, the drum has an external diameter of 6 ft. $4\frac{3}{8}$ in., and although it is designed for a pressure of 1870 lb./sq. in., it has successfully undergone pressure tests of up to 2855 lb./sq. in.

The first of a set of four drums of a similar size which E.S.C. is making for Willington, this forging began its existence as a 275-ton ingot, the product of three Siemens acid open hearth furnaces, this being the heaviest ingot ever cast in the British Commonwealth. Twenty-nine feet high and nine feet in body section, the ingot required six weeks annealing before the top and bottom "discards" could be removed and a hole trepanned through the centre to produce the 190-ton billet needed to make the forging. The forging operation on the drum itself, carried out under the 7,000-ton electro-hydraulic forging press, required fourteen "heats" in all, and the whole operation took two and a half weeks.

The engineering operations were performed in the company's 230,000 sq. ft. South Machine Shop, where, incidentally, the Queen and the Duke of Edinburgh, during the Royal visit to the Works last October, showed great interest in electronically controlled machining operations being carried out on this forging. An additional point of interest is that the five principal nozzles of the 45 fitted called for the greatest amount of welding which E.S.C. has ever undertaken in such products. There have also been fitted to the drum 76 stub tubes.



A special 100 ton flat top wagon was used to transport the drum by rail to its destination, where it was lifted into the building direct from the siding.

Heat Flow Problems

A select conference on heat flow problems, convened by the Institute of Welding, was held at the Selsdon Park Hotel on May 16th and 17th, and attended by about twenty investigators drawn from industry, the universities and research associations. There were four sessions, two on each day. The chair at the first two sessions was taken by Professor O.A. Saunders of Imperial College, and these were devoted to a general exchange of information and ideas, with the object of defining the present limits of knowledge and the fields in which further investigation is needed.

The discussions, opened by Mr. H. E. Dixon (B.W.R.A.) and Mr. J. F. Lancaster (A.P.V. Co., Ltd.), established the importance, especially in the case of the alloy steels and of the aluminium alloys, of making available acceptably reliable methods of calculating the thermal cycles occurring during welding. On the basis of such data, the welding engineer is able to predict the physical properties of the finished weld and of the heat-affected zone, and so to determine, without long and costly experiments, the welding procedures required to produce a satisfactory joint free from cracks and without excessive distortion.

In opening the third discussion, Dr. A. A. Wells (B.W.R.A.) described the formulae, devised originally for purposes other than welding, for the calculation of the heat flow in the plate, and explained certain simplifications which could be adopted without materially reducing the accuracy of the results. Other methods of calculation were described by Dr. P. H. Price (Sheffield University) and Dr. A. V. Brancker (Northern Aluminium Co., Ltd.), and Mr. E. V. Beatson gave an account of practical experiments in connection with the resistance welding of carbon steel studs to plate material. A similar contribution, describing experiments conducted at Birmingham University and concerned with the correlation between the thermal effects predicted by the formula developed by Dr. Wells and those observed in the practical tests, was made by Mr. D. R. Milner in the concluding session. Possible improvements in the efficiency of existing measuring equipment were also discussed.

There was general agreement that further work requires to be done, on both the theoretical and the practical sides in order to provide the welding engineer with simple and trustworthy methods of calculation. The Conference therefore set up a Continuation Panel to collect and distribute information about work done and projected. Enquiries may be addressed to the Secretary (Heat Flow Panel), The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

NEWS AND ANNOUNCEMENTS

Fatigue of Metals Course

A WEEK's Residential Course on the Fatigue of Metals is being held at the University of Nottingham from Monday, September 12th, until Friday, September 16th, inclusive. The course has been organised by a joint committee of industry and the Engineering Departments of the University under the chairmanship of Mr. G. Forrest. As a considerable amount of research on the fatigue of metals is carried out at Nottingham, it is appropriate that such a course should be centred there.

It is intended that the course should present the known facts concerning the fatigue of metals to the practising engineer, and, although no formal academic qualifications are required for enrolment, it will be assumed that those attending the course will possess either a degree or the Higher National Certificate in engineering or science.

The subjects to be covered are : the fundamentals of fatigue ; the fatigue properties of steels and cast iron ; the fatigue properties of non-ferrous alloys ; corrosion fatigue and fretting corrosion ; fatigue in aircraft ; and fatigue testing.

The fee for the Course (inclusive of advance copies of the lectures) is 10 guineas, and residential accommodation for 100 people will be provided (at a cost of 7 guineas a head) in Hugh Stewart Hall, which is situated in the University Park. All enquiries regarding the course should, be addressed to : The Secretary, Fatigue of Metals Course, Departments of Civil and Mechanical Engineering University of Nottingham, University Park, Nottingham.

Edwards High Vacuum, Ltd.

SINCE the early days of the war, W. Edwards & Co., (London) Ltd., have endeavoured, with no little success, to make the name of " Edwards " and " High Vacuum " synonymous, but the Company feels that the time has come to incorporate the two, in view of the many new fields of industry and research into which their products now take them, and in view of the considerable expansion in export business. The Company will, therefore, be known in future as Edwards High Vacuum, Ltd.

Despite the fact that the new Crawley factory covers a much larger area than the London premises it replaced, a further 40,000 sq. ft. of floor space has been added at the rear of the building. Some of the latest developments in the fields of chemical engineering and vacuum metallurgy have necessitated extra space, quite apart from the expansion in sale of the Company's normal line of products.

Baker Platinum—Hanovia Merger

BAKER PLATINUM, LTD., Hanovia Products, Ltd., and Hanovia, Ltd., have now linked up as one company under the name of Engelhard Industries, Ltd. Baker Platinum is engaged in the refining and fabrication of precious metals the production of dental golds and amalgam alloys and the manufacture of platinum laboratory apparatus, etc. Other products include the Deoxo plant for catalytic gas purification and the Nitroneal Generator. It will form the Baker Platinum Division, Engelhard Industries, Ltd., 52, High Holborn, London, W.C.1.

Hanovia Products manufacture liquid gold and other liquid preparations for the ceramic trade, and will form Hanovia Products Ceramics Division, Engelhard Industries, Ltd., 146, Vauxhall Street, Kennington, London, S.E.11. Hanovia Lamps, makers of ultra-violet and infra-red radiation equipment, will become Hanovia Lamps Division, Engelhard Industries, Ltd., Bath Road, Slough, Bucks.

Engelhard Industries, Ltd., have branch offices in Australia, Belgium, Brazil, Denmark, France, Italy, Japan, South Africa, Switzerland, and associated offices throughout the U.S.A. and Canada.

Fuel Efficiency Course

A RESIDENTIAL refresher course for works and plant engineers on " Current Practice in Fuel Efficiency " is to be held at the Clarendon Laboratory, Oxford, from September 26th to 30th, 1955, under the auspices of the National Industrial Fuel Efficiency Service, with the support of the Southern Regional Council for Further Education. There will be fifteen sessions at which lectures will be given by specialists in various branches of fuel technology. The fee for the course will be nine guineas inclusive of meals and accommodation at Brasenose College. A copy of the preliminary programme and registration form, together with any further information required, can be obtained from the Course Secretary, Mr. E. S. Watkin, Ailsa House, 181, Kings Road, Reading, Berks.

Coking Plant Order

WOODALL-DUCKHAM CONSTRUCTION CO., LTD., announce that they have just received another order for a coke oven plant valued at about £1¾ million from the South African Iron & Steel Industrial Corporation Ltd. This further plant will be sited at Pretoria, and is in addition to the two coke oven plants, located at Vanderbijl Park and Pretoria, respectively, ordered by the Corporation from the same company in November last year. The total value of these three plants, which will be capable of carbonising more than 1¼ million tons of coal per year, will be about £3½ million.

Aluminium-Wound Transformer for Kitimat

THE world's largest aluminium-wound power transformer is now under construction in the St. Catharine's, Ontario plant of the English Electric Company. It will play an important part in the expansion now under way of the Kitimat, British Columbia, smelter of the Aluminum Company of Canada. The current expansion programme, started last October, will add 60,000 tons to Kitimat's present aluminium production capacity of 91,500 tons a year by the end of 1956. A further expansion now authorised for completion in 1959 will bring the total production capacity to 331,500 tons a year.

The English Electric unit will transform 70,000 kVA from 275 kV to 13·2kV, and is believed to be the largest

ever built with aluminium windings. The total length of the aluminium wire, rectangular in cross section, will be well over 42 miles: it will weigh approximately 11,000 lb. The H.V. winding wire will be insulated with an appropriate number of paper layers, and the L.V. wire will have an extra-heavy Formel coating. Alcan already has a number of aluminium-wound transformers in operation in various places, and all have given completely satisfactory service. They range in size from 220 to 20,000 kVA. Aluminium was selected for the winding material of the new 70,000 kVA. unit in order to provide an opportunity for a major electrical manufacturer to study the design and economics of aluminium in a large power transformer. This will provide practical data required for the future development of this aluminium application.

Climax Molybdenum Changes

Mr. C. M. Loeb, Jr. (U.S.A.), and Mr. R. L. Prain, O.B.E., have resigned from the Board of Climax Molybdenum Company of Europe, Ltd., and have been succeeded by Mr. A. H. Bunker (U.S.A.) and Mr. R. E. Warriner (U.S.A.). Mrs. J. Critchley has been appointed Secretary on the resignation of Mr. H. L. Richardson. The Registered Office of the Company has been transferred to 99, Pinstone Street, Sheffield, 1.

Hungarian Bentonite Exports

The big export possibilities of Hungarian bentonite are stressed in an article in the Hungarian periodical *Nature and Society*. Hungary is rich in bentonite, a mineral of great importance as a binding agent in many industries, including iron-founding, ceramics, constructional engineering, rubber and linoleum making, dyeing, manufacturing fire-resistant materials, and for soil-improvement. The article claims the montmorillon constituent of Hungarian bentonite is "unique in the world," giving a binding capacity and compressive strength superior to the American variety.

Poland, the article says, is taking considerable quantities of foundry and drilling bentonite, and big exports are being made to Sweden, Switzerland, Norway. East Germany and Austria are also taking consignments, and preparations are being made to export to Britain, West Germany and Finland.

Head Wrightson Acquisition

Head, Wrighton & Co., Ltd., have acquired from The British Metal Corporation, Ltd., the entire share capital of Colliery Engineering, Ltd., of Sheffield, and its subsidiary, The Cupola Mining & Milling Company. The latter is now a direct subsidiary of Head, Wrightson & Co., Ltd., with Sir John Wrightson, Bt., as Chairman, Mr. A. Chilton as Managing Director, and Messrs. Peter Wrightson, L. W. Needham, and H. Cussons as Directors. The Board of Colliery Engineering, Ltd., has been reconstituted as follows: Mr. Peter Wrightson, Chairman; Mr. L. W. Needham, Managing Director; and Messrs. H. Cussons and S. A. Casson, Directors.

Materials Handling Journal

The first issue of a new controlled circulation quarterly, *Materials Handling News*, dealing with all types of labour-aiding machinery, was published on July 1st by *Mechanical Handling*, the journal which organises the Mechanical Handling Exhibition. The first issue shows, among other things, what is to be gained from mechanisation; how handling costs can be reduced; how the latest labour-aiding equipment saves money and man-hours; how the loading and unloading of lorries should be organised for maximum efficiency; and discusses some of the latest equipment. Readers wishing to receive copies of *Materials Handling News*, which has a modern newspaper format, should write to Dorset House, Stamford Street, London, S.E.1.

$11½ Million Contract for B.T.H.

The British Thomson-Houston Co., Ltd., recently received a contract valued at $11½ million (£4·1 million) for development and production of military electronic equipment for supply to N.A.T.O. countries. The contract has been negotiated with Hazeltine Electronics Corporation of New York City acting on behalf of the United States Navy Department. The total value of U.S. Government orders now placed with B.T.H. for military electronic equipment, including fire control, radar, etc., amounts to $26 million (£9·2 million). In addition, B.T.H. has in the past five years supplied to European and Commonwealth countries direct £6 million worth of military radar apparatus.

Land Pyrometers in U.S.A.

Land Pyrometers, Ltd., of Sheffield, have now completed arrangements for the sale of their products in the United States of America, through the Fielden Instrument Division of the Robertshaw-Fulton Controls Co. It is noteworthy that British-made instruments produced by Land Pyrometers have aroused considerable interest in the United States, particularly the Land surface pyrometer, no similar instrument of comparable accuracy being available there, and the Land portable glass pyrometer, which is the only commercial pyrometer capable of measuring the surface temperature of glass.

Two-Stage Gas Producer

It is announced by the International Furnace Equipment Co., Ltd., of Aldrich, Staffordshire, that they have received from the English Steel Corporation Ltd., of Sheffield, a further order for a GI two-stage generator for the production of clean gas. This is the third plant of this type to be installed at the River Don Works of the English Steel Corporation Ltd., two others having been installed about a year and a half ago.

This particular type of gas producer plant is claimed to be superior, both as regards performance and economics of operation, to the conventional single-stage plant.

Wealth in Red Mud

Hungary is taking steps to extract a wealth of raw materials lying in a million tons of "red mud" which have accumulated in flats around her aluminium factories. Red mud is the "waste" left over after bauxite has been treated for the extraction of alumina, of which Hungary is the prime producer in Europe. As the red mud has a 25% iron ore content it is estimated that 250,000 tons of iron ore are awaiting reclamation.

Processing of red mud has been going on on a moderate scale since 1948 at a plant in Diósgyör, where manganese mud and ore powder are added and the mixture shaped

into bricks and baked before transporting to the local blast furnaces, where they are tipped in with iron ore in a 7·7% proportion. The bricks, with a 40% iron content, are stated to exceed the quality of domestic ore from Rudabánya. Present output of the factory is 200 tons a day, but the iron works could take very much more, so the output is to be greatly increased by more efficient processing.

Iron ore is not the only product of red mud, however. The Metal Research Institute has found that 330 lb. of pure alumina and 220 lb. of caustic soda can be obtained per ton, together with a large quantity of titanium oxide. The processed red mud can then be made into bricks of even higher iron ore content than previously.

Processing is to be started in an experimental plant to be built this year at a cost of £180,000. It is due to start working in the last quarter of the year.

Kent Sales Changes

Export sales of measuring and control equipment made by George Kent, Ltd., reached the record figure of one million pounds sterling in 1954; and this expansion, together with that of home sales, has necessitated some expansion and re-organization of the Kent Sales staff. One effect of this is that MR. J. M. WHITE, lately Chief Sales Engineer, has been appointed to the London Office. MR. J. THAM has been appointed Chief Sales Engineer in succession to Mr. White.

Personal News

THE FOLLOWING changes are announced in the Management of The Mond Nickel Co., Ltd., and Henry Wiggin & Co., Ltd.: MR. L. K. BRINDLEY, M.B.E., has been elected Deputy Chairman of the Boards of the two Companies, and MR. G. ARCHER, C.M.G., has been appointed Managing Director of Mond Nickel; MR. I. A. BAILEY is moving his headquarters from Birmingham to London, where he will continue as a Director of Mond Nickel and as Managing Director of Henry Wiggin; DR. L. B. PFEIL, O.B.E., F.R.S., has relinquished the Managership of the Development and Research Department, in order to devote himself more fully to Directorship responsibilities, and is succeeded by MR. F. DICKINSON; MR. R. A. R. HILL has been appointed as Director of Mond Nickel and Comptroller of both Companies; MR. F. B. HOWARD-WHITE has been appointed a Director of Henry Wiggin and Secretary of both Companies; MR. J. O. HITCHCOCK has been appointed Sales Director and a Director of Mond Nickel; MR. A. P. HAGUE continues as a Director of both Companies; and DR. A. G. RAMSAY as a Director of Mond Nickel, resident in South Wales.

BIRLEC, LTD., announce the appointment of MR. K. L. MOON as Sales Manager of their Induction Heating Division. MR. A. E. PICKLES continues as Manager of the Division, with overall responsibility, and MR. R. ABBOT as Technical Manager.

SAMUEL FOX & CO., LTD., announce that MR. G. R. BOLSOVER (Director and Consulting Metallurgist) retired from the Company's service on June 30th, 1955. MR. R. D. POLLARD has been appointed to the Board and becomes Director and Chief Metallurgist. MR. D. INMAN also retired from his position as Director of Developments at the end of June, but his services are being retained as Engineering Consultant to the Company and he will remain a member of the Board.

MR. T. POWELL, Managing Director of British Electro Metallurgical Co., a Division of Union Carbide, Ltd., has been appointed to the Board of British Acheson Electrodes, Ltd., in the capacity of Deputy Managing Director.

SIR James CHADWICK has been elected an Honorary Fellow of The Institute of Physics.

MR. H. J. PODMORE has been appointed Sales Manager of the specialist Dryer Division of Birlec, Ltd. MR. T. C. SAUNDERS continues as Manager, with overall responsibility, and MR. J. W. CARTER as Technical Manager of this Division.

TO MARK the completion of 50 years' service with David Brown & Sons (Huddersfield), Ltd., MR. A. SYKES, Technical Director of the Company, was presented by his fellow directors with an engraved silver rose bowl at a luncheon in his honour on June 8th.

MR. W. J. G. COSGROVE has been appointed to Special Duties with Electric Resistance Furnace Co., Ltd., from June 1st, 1955. MR. H. KNIGHT is now Manager of the Heat Treatment Division of Electric Furnace Co., Ltd., at Burton-on-Trent.

MR. D. I. KING, formerly Editor of *The British Steelmaker* and of *The Master Builder*, has joined The United Steel Cos., Ltd., as Technical Press Officer. He will be responsible to Mr. C. W. Hervey, United Steel's Public Relations Officer, and will concentrate on supplying information on the Company's activities to the trade and technical press. He will later take over the editorship of a new house journal to be launched in September under the title of *News from United Steel*.

EDWIN DANKS & CO. (OLDBURY), LTD., announce the retirement of MR. W. F. JOHNSTON, their Chief Engineer. He is succeeded by MR. H. MCANDREW.

MR. R. W. BURCHHARDT, Technical Manager, has been appointed a Director of Colloidal Graphite, Ltd.

MR. R. L. GREEN has joined Winston Electronics, Ltd., as Senior Development Engineer responsible for telecommunications research and development.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce the appointment of MR. H. H. DAKER as Patents Officer in succession to the late MR. R. L. CLEAVER.

MR. E. CATTANES has joined The Solartron Electronic Group, Ltd., as a Senior Commercial Executive. He will be responsible for developing the European export market for Solartron electronic instruments.

EDWIN DANKS & CO. (OLDBURY), LTD., announce the retirement, due to ill health, of MR. R. C. NASH. Mr. Nash joined Babcock & Wilcox in 1910, and transferred to Edwin Danks in 1924 to take charge of the Estimating Department. He was appointed Chief Assistant to MR. J. SMITH, the Managing Director, in 1943.

MR. E. R. SISSON, has been appointed Technical Services Manager to Smiths Aircraft Instruments, Ltd., in succession to Mr. Langmead who died recently.

RECENT DEVELOPMENTS

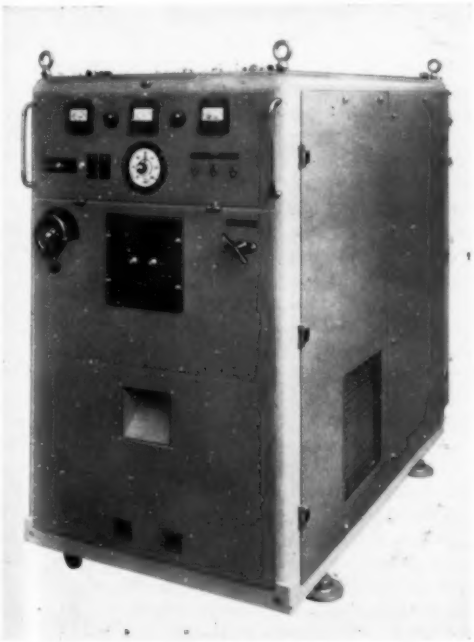
MATERIALS : PROCESSES : EQUIPMENT

12 kW. Induction Heater

THE new induction heater, Type EH.120, designed and manufactured by E.M.I. Factories, Ltd., is very flexible in operation, due to the versatile output coupling arrangements which enable it to be used conveniently for a very wide range of heating processes, either on a built-in work station or at a remote work station supplied through a transmission line. Moreover, the generator is entirely self-contained, the only external connection being to a 3-phase supply.

R.F. power output is 12 kW. for continuous, or 14 kW. for intermittent working (50% duty cycle) into work of high power factor, or 500 kVA. and 700 kVA., respectively, into work of low power factor, or where the coupling efficiency is low. A hand-wheel on the front control panel provides a smooth and continuous control of the R.F. voltage supplied to the output terminals.

Work-matching capacitors in varying combinations up to 0·14 mfd. are incorporated, but in cases where R.F. power is fed to a remote work position via a transmission line, the capacitor can readily be omitted. The continuously variable output coupling system is very suitable for feeding into a co-axial line, and a dual-range line ammeter on the control panel facilitates accurate matching to a transmission line and external work circuit. For accurate timing of operations, a timing unit with built-in hour meter is incorporated. The normal range is 0–30 seconds, but other ranges from 0–10 seconds up to 0–4 hours are available to order.



E.M.I. Type EH. 120 12 kW. induction heater

Air and water cooling arrangements are entirely self-contained, and the equipment will operate continuously without any external water supply. A motor-driven centrifugal air blower and water pump, in conjunction with an ample reservoir tank and car-type radiator block provide adequate air-cooling for the valves and water-cooling for the work coil and main oscillator coil. A washable dust filter is fitted to the air intake, and the whole of the cooling system is housed within the cabinet. The equipment is provided with extensive control and metering facilities, and is completely safeguarded against overload. Power requirements are 340–445 volts, 3-phase, 50 cycles; consumption at 12 kW. output—23 kW., and in stand-by condition 2·6 kW. Power factor at full load is 0·88.

E.M.I. Factories, Ltd., Hayes Middlesex.

Range of Phosphating Processes

THE JENOLIZING CO., LTD., are now manufacturing and marketing processes covering the entire phosphating field. These processes, applicable by immersion or spray plant, may be split into two main types—unaccelerated and accelerated. Unaccelerated solutions, implying slow rates of crystal growth, favour the development of coarsely crystalline coatings. Accelerated solutions, on the contrary, tend to spread rapidly over the steel surfaces and restrict pickling action. Thus, these coatings are usually finer in texture, lighter in weight and dissolve smaller quantities of the surface metal than their unaccelerated counterparts.

The Jenolizing range employ manganese, zinc and iron phosphates forming tightly adherent, densely packed, insoluble, inert, crystalline phosphate coatings on ferrous metal surfaces. They are coded as follows: JM (unaccelerated manganese), JAM (accelerated manganese), JAZ (accelerated zinc), and JF (unaccelerated iron). Hitherto, industry has inclined more towards zinc phosphating processes, due to their ease of application. While producing a complete range, the Jenolizing Company are especially concerned with developing the scope of manganese processes, which are claimed to give superior paint adhesion and anti-corrosion protection. Typical applications for Jenolizing processes include the treatment of hot and cold rolled sheet, forgings and extruded steel, precision and machined parts, and steelwork to be cold drawn or stamped.

The Jenolizing Company also produce a process, known as COP, for treating aluminium and its alloys. Its purpose is to replace the natural oxide film, which presents serious problems of paint adhesion, with a coating which greatly improves adhesion and inhibits corrosion. The coatings are unaffected by bending or rolling: sheets can be bent to sharp angles without diminishing the protective action of the coatings. In addition to bonding paints, lacquers and synthetic enamels, the coatings lend themselves to excellent dye finishes in a wide range of colours.

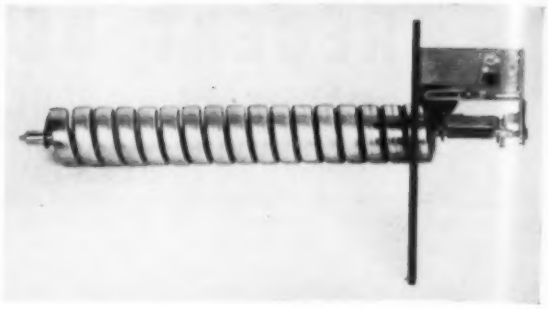
Jenolizing Co., Ltd., 13–17, Rathbone Street, London, W.1.

Pressure Element

A NEW range of pressure elements known as the 200 Series has recently been introduced by Foxboro-Yoxall, Ltd., and one of these, the Type 250 Heavy Duty Helical is shown in the accompanying illustration. The aim has been to produce an element capable of measuring the very highest pressures with sustained accuracy, long life and high safety factor. Thus this new helical element will measure pressures up to 80,000 lb./sq.in., higher than has hitherto been possible by mechanical means.

The element is built of a molybdenum-bearing stainless steel and is particularly suited to the measurement of continuously fluctuating pressures in the very high ranges: it can be used in many applications where corrosive vapours may be present. Care has been taken to minimise the possibility of damage through over-ranging, and wide safety margins are provided. For example an element for the range 0–10,000 lb./sq.in. may be overranged in safety to 18,000 lb./sq.in. A further feature is the provision of expanded scale reading, an element designed for 9,500 lb./sq. in. having a range from 9,000 to 10,000 lb./sq.in., with the result that the clarity and accuracy of the readings are greatly improved.

*Foxboro-Yoxall, Ltd., Lombard Road, Merton, London, S.W.*19.



Foxboro-Yoxall Type 250 heavy duty helical pressure element.

Cam-Operated Programme Controller

HONEYWELL-BROWN, LTD., announce the addition of an Electronik circular chart cam-operated programme controller to their range of industrial instruments. This controller utilises a transparent plastic cam, the contour of which is shaped to the desired time-temperature pattern. The cam rotates, and a cam roller with a follower arm continuously transmits the contour of the cam to the instrument control set point. Wherever material is heated (or cooled) at a fixed rate, held at some temperature for a certain period, then again cooled (or heated) at a controlled rate, the programme controller ensures uniform reproduction of the operation. Variables such as strain, weight, speed, etc., can be similarly programmed. The typical process applications of the instrument include annealing, ceramic firing, controlled condition testing, drying, heat treating, plastic polymerisation, research, retort cooking, and vulcanising.

Electronik cam-operated programme controller

Honeywell-Brown, Ltd., 1, *Wadsworth Road, Perivale, Greenford, Middlesex.*

Aluminium Anti-Corrosive Coating

A NEW aluminium dampcoating product has been developed by Xzit Chemical Company of Hoboken, U.S.A., for engineers and maintenance personnel faced with the problem of applying effective corrosion preventatives to dark surfaces which are damp, wet or sweating.

For some 15 years the company has been manufacturing a protective coating called Serviron—a black, permanently soft, self-healing, viscous coating material. The non-toxic, odourless Serviron was designed for the protection of submerged and exposed steel surfaces which undergo severe corrosion, for which functions it proved ideal. It was used successfully on water tank interiors, underground pipe lines, piers, ships' hulls, subways and deck machinery. The coating was manufactured only in the one colour, and engineers often found the black material hard to apply without leaving areas that had been missed. The dark surface made inspections difficult and painters wanted a lighter, more pleasant colour with which to work.

After years of research, Xzit tried aluminium pigments which, being non-toxic, highly reflective, durable and moisture resistant, were ideally suited to their needs. Aluminium Serviron was produced after months of development and testing work by Xzit and the Aluminum Company of America, suppliers of the pigment. Marketed only recently, this new dampcoating material has proved extremely successful. Non-toxic in all respects, it is ideally suited for coating drinking water tanks. Its bright colour facilitates inspection in poorly illuminated areas such as ships' tanks. It is also much pleasanter to work with. Aluminium Serviron is now manufactured in Great Britain.

Xzit (G.B.), Ltd., 175, *Piccadilly, London, W.*1.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
JULY, 1955 Vol. LII, No. 309

The Decomposition of Blast Furnace Raw Materials and Slags, Steelmaking Slags and Refractories for the Purpose of Chemical Analysis

By E. W. Harpham

Richard Thomas and Baldwins Ltd., Ebbw Vale Works, Mon.

The chemical analysis of oxide-bearing materials can only be carried out successfully if complete decomposition of the sample is obtained. Methods for the decomposition of iron ores and related materials, slags and refractories of widely varying composition are referred to, and many of them described in detail. The first part of the paper includes a general discussion of the techniques used, and in the concluding part, to be published next month, the application of the methods will be considered.

1—INTRODUCTION

THIS paper is a survey of the methods of decomposition which have been used for the transposition of the materials concerned (oxide-bearing materials) into solutions suitable for the chemical determination of one or more constituents of those materials. No attempt is made to cover the procedures employed in the rational analyses of any of the materials under discussion, for example, the determination of free quartz.

The importance of obtaining the complete decomposition or solution of the test sample, if accurate quantitative chemical analyses are to be carried out, cannot be over-emphasised. The success of the analysis depends in large measure on the care and thought with which the solution has been prepared. This cannot be accomplished by blindly adhering to one set of directions; each case must be considered on its own merits.

There is very little of a general nature that can be said regarding the decomposition of such a great diversity of substances as are dealt with in this paper, except (*a*) that the method of obtaining the material in a suitable solution must be such that it does not lead to the volatilisation of the desired constituent, and (*b*) that care must be taken to prevent any mechanical loss. The latter is most important when the percentage of the constituent that is sought is high. The final choice of the method of preparing a suitable solution of the material for chemical analysis is controlled by the element or elements that are to be determined. A method of decomposition that provides a suitable solution for the determination of a single element may not always be satisfactory if the solution is to be used for the determination of a number of elements. A knowledge of the elements and/or compounds that are likely to be present in the material under examination is of much value to the chemist, as it will greatly aid his selection of a suitable method of decomposition.

2—CLASSIFICATION OF THE MATERIALS UNDER DISCUSSION

The materials which are dealt with in this paper, as suggested by its title, cover a very wide field indeed, and for purposes of discussion will be considered under the following three main headings:

A—Iron- and Steelmaking Raw Materials.
B—Iron- and Steelmaking Slags.
C—Refractory Materials.

A—Iron- and Steelmaking Raw Materials.

Under this heading are included all the sources from which iron is made on the commercial scale, together with the usual slag-forming materials and fluxes. Although coke is an important constituent of the blast furnace burden, it will not be considered here, as it is outside the scope of work intended for this paper.

There are a large number of different iron ores, ranging in iron content from 30% to nearly 70%, and for which different decomposition treatments have to be applied. Other sources from which iron is obtained, and which can be included in this section, are tap cinder, mill scale and the various iron sinter products. Manganese ore can also be included here as a raw material. The fluxes limestone, lime and fluorspar are also iron- and steelmaking raw materials.

B—Iron- and Steelmaking Slags

In this category must be considered all types of slags produced in the manufacture of iron and steel by the various processes—the blast furnace, open hearth furnace (acid and basic), Bessemer converter, electric furnace, cupola, rotary furnace, etc. By virtue of the very complex nature of slags, any compound or constituent falling wholly, or in part, in the various oxide systems which constitute the slags has to be considered.

Further complications are introduced in basic open hearth and basic electric furnace slags, owing to the use of

fluorspar in the working of the charges. Some of these slags carry as much as 7% of calcium fluoride, and in these cases special methods of decomposition have to be employed.

C—Refractory Materials

The refractory materials used in present-day iron- and steelmaking practice are also of a very diverse nature and, for the purpose of this paper, will be considered under the three main sub-headings as follows:

(*a*) Acid or Siliceous Refractories.
(*b*) Basic Refractories.
(*c*) Neutral Refractories.

This classification is a purely arbitrary one, but it has the advantage that it indicates in a general way the type and behaviour of the various refractory materials from a chemical point of view. Certain types of refractories, such as occur in the wide range of aluminous materials, for example, sillimanite, mullite, etc., may be classified as either basic or neutral. For convenience, they will be considered as basic materials in this paper.

(*a*) *Acid or Siliceous Refractories.*

In this group are included such raw materials as quartzites, sands, ganister and all the different varieties of clays, together with the manufactured and fired products, such as silica and semi-silica bricks, firebricks, and other refractory shapes and articles made from this class of refractory material.

(*b*) *Basic Refractories*

The chief basic refractory materials of commerce include dolomite, magnesite and magnesia, alumina and bauxite, and certain refractory substances containing zirconium. As stated above, the various alumino-silicate materials comprising mullite ($3Al_2O_3 \cdot 2SiO_2$), sillimanite ($Al_2O_3 \cdot SiO_2$), cyanite ($Al_2O_3 \cdot SiO_2$), andalusite ($Al_2O_3 \cdot SiO_2$), etc. will also be considered in this group. It should be noted that bauxite (a hydrated aluminium oxide) by itself is not generally used as a refractory, but it is considered because suitable methods for "opening-out" this type of material have been formulated.

(*c*) *Neutral Refractories*

The class of neutral refractories covers a very miscellaneous and widely differing variety of materials. In this paper, the various chrome refractories, comprising chromite (chrome iron ore) and the various chrome-magnesite compositions (chrome spinels—$RO \cdot Cr_2O_3$), and carborundum will be considered. Carbon refractories, which are now being widely used in the construction of blast furnace hearths, should also be included in this group of refractory materials. Very little work, however, appears to have been carried out on the chemical analysis of carbon refractories, the examination having been more of a physical nature. Even the work that has been published is very contradictory, and under the circumstances will not be considered.

3—METHODS OF DECOMPOSITION

Quite a variety of methods have been used to get the test sample into solution. These range from attack by the action of acids and alkalies or special solvents and solutions, heating with a reagent (flux) at an elevated temperature, to decomposition with the aid of gaseous compounds. Water (sometimes called the universal solvent) is of no value as a direct solvent for the kind of materials under consideration, although it is interesting to note that the late Dr. W. J. Rees[1] carried out some experiments on the decomposition of silica and fireclay refractories, using super-heated water in an autoclave, but the results were not at all satisfactory.

The various methods of decomposition which are applicable to the particular types of materials herein considered will now be discussed in some detail. They can be conveniently considered as follows:

A—Wet Methods of Decomposition.
B—Decomposition by the Use of Fluxes at Elevated Temperatures.
C—Special Methods of Decomposition.

Detailed instructions for carrying out the various decomposition procedures, with particular reference to the determination of iron, are given in Appendix II.

A—Wet Methods of Decomposition

Depending on the type of material under consideration, wet methods of decomposition usually comprise attack by aqueous solutions of the mineral acids, used either alone or in combination with one another. Aqueous solutions of the alkalies are of no value in this respect. Wet methods of decomposition are usually carried out in glass vessels (except when hydrofluoric acid is used), and, generally, no provision is made for retaining any elements that are rendered volatile under the prevailing conditions.

Hydrochloric acid is preferable if the material is decomposable by an acid. This is especially true if the material concerned is very rich in iron—for example, iron ore. If silica is to be determined in the resulting solution, treatment with sulphuric acid or perchloric acid may follow. Perchloric acid is preferable to sulphuric acid, especially if appreciable amounts of alkaline earth metals are present, owing to the much greater solubility of the perchlorates of these metals, and of perchlorates generally, than of the sulphates. It must be remembered that if fuming with perchloric acid is to be carried out, prior oxidation of the solution with nitric acid is necessary.

Perchloric acid[2] may be used alone or together with other mineral acids for the initial decomposition of a wide variety of minerals, slags and refractories[3], and it is finding increasing use in metallurgical analysis. Hydrochloric and perchloric acids give solutions which are suitable for composite schemes of analysis.

Nitric acid is used almost exclusively as an oxidising agent, rather than as a solvent, and hydrofluoric acid is used, generally together with another acid, when silica is to be eliminated. When hydrofluoric acid is used, it is essential that all traces of it should be removed before proceeding with the analysis, either by evaporating to fumes with sulphuric acid or perchloric acid, or by heating the dried residue in a muffle furnace to the complete expulsion of the fluorine. Platinum apparatus should be employed when using hydrofluoric acid.

Acid decomposition procedures should be used whenever possible, even though the decomposition is incomplete. Any undecomposed material is collected, fused with a suitable flux, and the solution of the melt added to the original solution. The advantages of this general procedure are obvious.

Decomposition with acids may also be carried out at elevated temperatures by operating in sealed glass tubes[4]. As this method of decomposition is not so well known, one method of operation will be described. A piece of

Pyrex glass tubing, between 30 and 40 cm. long, 16 to 18 mm. internal diameter, and with walls over 3 mm. thick, is sealed at one end so that the glass is not thickened into a blob. The tube is washed and dried, and the dry sample is introduced into it in such a manner that the sample does not touch the side of the tube near the open end. The necessary acid is added by means of a long-stemmed funnel without wetting the sides of the tube at the open end. The tube is then sealed off in a flame in such a manner that a capillary end, 2 to 3 cm. long, is left on the tube : this is sealed off at the tip. The sealed tube is placed in a metal cylinder having a screw cap, and the whole placed in a cold tube furnace which is gradually heated to the desired temperature for a prescribed length of time and then allowed to cool. When quite cold, the glass tube is withdrawn from the metal container and the capillary tip heated gently until the glass softens. Any pressure inside the tube will blow a vent hole in the glass. When the pressure has been relieved, a mark is filed on the glass tube below the base of the capillary and the end broken off. The contents of the tube are then washed out into a suitable container and treated as required.

The principle of the above method is not new. It was used by Jannasch[5] many years go for decomposing silicate rocks, and, in view of the successful results recently obtained by using this method, and the advantages it offers, particularly if the supply of material is scanty, it would repay further study with a view to its wider adoption. Some applications of this method to various materials will be described later in Section 4—"Application of the Methods".

B—Decomposition by the Use of Fluxes

large number of fluxes have been proposed for decomposing the varied types of oxide-bearing materials under consideration. Many of these fluxes are suitable for "opening-out" certain materials for the determination of one constituent only; many more are now obsolete or find application only in special circumstances. With few exceptions, the fluxes most commonly used in present day practice are compounds of the alkali metals, and comprise the hydroxides, peroxides, carbonates and borates, which act as basic fluxes, the bisulphates, pyrosulphates and acid fluorides being the chief acid fluxes.

At the fusion temperatures the alkaline peroxides are powerful oxidising agents as well as disintegrators, and all elements are oxidised to their highest valency states. Fusion with the alkali carbonates also effects oxidation of many elements, but at a much slower rate than that of the peroxides. In order to accelerate the oxidation, various oxidising agents are often mixed with the carbonate, for example, an alkali nitrate, nitrite, chlorate, permanganate (if manganese is not to be determined) or peroxide. The use of a nitrite is preferable to that of a nitrate. When a nitrite is used, not nearly so much frothing takes place, it does not attack the platinum vessel so much, and it is equally as effective as the nitrate. The sulphate fluxes also have an oxidising action on some elements, but their oxidising action is very mild compared with that of the carbonates. Ferrous iron is readily oxidised to ferric iron in a sulphate fusion, but neither 2-valent manganese nor 3-valent chromium are oxidised under the same conditions.

Probably the most frequently used flux is anhydrous sodium carbonate, which, according to Mellor[6], was first used by T. Bergmann in the 18th Century, and which can be used for the decomposition of a large number of substances. It has a melting point of 852° C. and it can now be obtained commercially in a state of high purity. The preparation of pure sodium and potassium carbonates for use in fusion procedures has been described by Smith[7].

Fusions with sodium carbonate (and potassium carbonate) should ordinarily be carried out in platinum vessels, or in vessels of palladium alloyed with gold. It has been known for a long time that in sodium carbonate fusions there is some attack on the platinum vessel used due to the thermal decomposition of the sodium carbonate—$Na_2CO_3 \rightarrow Na_2O + CO_2$, the sodium oxide combining with the platinum to form sodium platinate, which ultimately finds its way into the solution of the material under examination. This aspect of fusions with sodium carbonate has recently been studied[8], and it has been shown that this attack can be almost entirely prevented by carrying out the fusions in an atmosphere of carbon dioxide.

Sodium bicarbonate has also been recommended as a flux in place of sodium carbonate by Holthoff[9], on the grounds that it was more easily obtainable in a pure state, but this no longer applies.

Potassium carbonate, because of its hygroscopic nature, is less suitable as a flux, generally, than the sodium salt, but it finds occasional use, since, with certain elements, the products of fusion are more soluble than the corresponding sodium salts. It melts at about 900° C. with some decomposition, and it should be dehydrated immediately before use.

Mixtures of sodium and potassium carbonates are sometimes used. The so-called "fusion mixture", which is a mixture of 4·5 parts by weight of sodium carbonate and 5 parts by weight of potassium carbonate, is the most fusible mixture of the two compounds. This mixture is sometimes recommended for "opening-out" certain materials in preferance to either of the carbonates alone, because of its lower melting point (712° C.).

Lithium carbonate[10] has also been used as a flux for "opening-out" certain silicate materials. Mixed with sodium carbonate, it was used by Gieseking and Snider[10] for decomposing certain silicates and soils, prior to the determination of potassium by the cobaltinitrite method. It begins to decompose at about 600° C. with rapid decomposition which is practically complete at 710° C. A mixture of 2 parts of sodium carbonate and 1 part of lithium carbonate melts at 470°–480° C.

The alkali hydroxides, sodium hydroxide and potassium hydroxide, although powerful fluxes, are used less frequently as decomposition agents, and then more often for the purpose of carrying out an assay than for a complete analysis. When heated, they give off water more or less copiously, and great care must be exercised in their use. The sample and flux should not be mixed together and then heated. Rather, the flux should first be heated by itself until most of the water has been driven off and the sample then added in small portions at a time, if it is known that the reaction will not be too violent. Otherwise the flux should be allowed to solidify and the sample spread on top of this solid mass before heat is again applied. Fusions with alkali hydroxides are usually carried out in nickel, silver or gold crucibles. The melting points of potassium hydroxide and sodium hydroxide are given in the literature as 360° C. and 318° C., respectively. Van Nieuwenberg and Dingemans[11] used the fused caustic alkalies in a nickel crucible to

decompose a number of technical silicates satisfactorily. With a temperature of fusion about 400° C., very little attack on the nickel crucible results if it is kept from direct contact with the flame. Scholes[12] used as a flux 1g. of sodium hydroxide and 3 g. of sodium nitrate per 0·5 g. of sample, and fused for 1 hour at 300° C. Mixtures of sodium hydroxide and sodium carbonate have also been used with satisfactory results[13].

Platinum is attacked by the fused caustic alkalies, the action no doubt being due to the formation of small quantities of the free alkali oxide, which combines with the oxygen of the air to give a peroxide, which attacks the metal.

The use of the alkali peroxides as fluxes is confined to sodium peroxide. This compound is a powerful disintegrator and the reactions are strongly exothermic. It gives off oxygen at all temperatures on heating, and great care must be exercised in its use, especially if unoxidised substances are present. The powerful disintegrating action of this flux may be tempered by mixing it with sodium carbonate, sodium hydroxide, calcium oxide, etc. As in the case of the caustic alkalies, sodium peroxide is more often used for industrial assaying, for example, the determination of chromium in chrome refractories, and where it is desired to bring a certain element to a required state of oxidation, rather than in making a complete analysis. In carrying out a fusion with sodium peroxide, the sample should be thoroughly mixed with the dry compound and the fusion carried out at the lowest possible temperature, either in a muffle or in a free flame. Although fusions with sodium peroxide are usually carried out in iron or nickel crucibles, platinum crucibles may also be used, if they are first lined by fusing a little sodium carbonate in them and allowing the carbonate to solidify in a thin layer on the bottom and walls of the crucible. In the subsequent fusion with sodium peroxide the lowest possible temperature should be used, insufficient to melt the carbonate lining. The use of crucibles made of zirconium for sodium peroxide fusions, in place of those made of nickel and iron, has been described recently by Petretic[18] and a number of advantages are claimed.

Recently Seelye and Rafter[14] and Rafter[15] have shown that certain minerals, resistant to decomposition by the usual methods, can be decomposed easily and completely at comparatively low temperatures, *circa*. 480° C., by heating with sodium peroxide in a platinum crucible, without any attack on the platinum, or in iron or nickel vessels with insignificant attack on the metal. Effective decomposition was attained with very finely powdered (240 B.S. sieve) material, mixed with 4 times its weight of sodium peroxide, covered with a light layer of the flux, and heated for seven minutes at 480° ± 10° C. in an electric muffle furnace. The rapidly cooled cake dissolves readily and completely in 50–100 ml. of cold water, or upon acidification. The following materials are reported to have been successfully decomposed in this manner—chrome refractory, bauxite, flint clay, zircon, chromite, wolframite, scheelite, rutile, magnetite, garnet, cassiterotantalite, titanite, beryl, black ilmenite, sand, glass sand, greensand, gypsum, celestite, barite, feldspar, basalt, rhyolite, trachyte and andesite. It should be noted that many of these substances can be decomposed at a much lower temperature (200° C.) than that quoted above, with, consequently, even less attack on the vessels.

A simple procedure for carrying out fusions with sodium peroxide is that recommended by Muehlberg[16] and later studied by Marvin and Schumb[17]. In this method the finely ground sample is mixed with sugar carbon and sodium peroxide, and the charge ignited by means of a fuse, the crucible being immersed in water during the ignition. It is claimed that there is little or no attack on nickel crucibles, but a small unfused residue may remain which requires special treatment. After a quantitative study of the method, Marvin and Schumb (*loc. cit.*) recommend 15 g. of a mixture of 150 g. of sodium peroxide and 10 g. of sugar carbon (100 mesh) for 0·5 – 1·0 g. samples. The application of this procedure to the decomposition of zirconium refractories is described in Section 4.

The sulphate fluxes that find most use are the bisulphates and pyrosulphates of sodium and potassium. The melting points of these compounds are as follows:

Sodium bisulphate—185° C.
Potassium bisulphate—219° C.
Sodium pyrosulphate—400° C.
Potassium pyrosulphate—414° C.

Ammonium bisulphate is sometimes used for certain substances in cases where no fixed alkali is wanted in the solution. Opinion seems to be divided as to which compound is the better one to use, the bisulphate or the pyrosulphate. On heating, the bisulphates give off a considerable amount of water in the early stages of the process with the formation of the pyrosulphate:

$$2MHSO_4 \longrightarrow M_2S_2O_7 + H_2O$$

and hence the fusion must be very carefully controlled in the beginning, in order to prevent any mechanical loss through frothing and spattering. With the pyrosulphates, on the other hand, the fusion is much more tranquil, hence the preference of some workers for the pyrosulphates. On prolonged heating, the pyrosulphates gradually lose sulphur trioxide with the formation of the normal sulphate:

$$M_2S_2O_7 \longrightarrow M_2SO_4 + SO_3.$$

Therefore, in prolonged fusions, it is advisable to allow the melt to solidify and to add one or two drops of concentrated sulphuric acid, again heating cautiously to regenerate the flux to its original active state, after which the operation is continued. It may also be advisable to make this addition of sulphuric acid at the end of a fusion if the decomposition of the flux has been at all appreciable. This will aid in dissolving the melt in the next succeeding operation, particularly if titanium or zirconium is present.

In some cases, the use of the sodium salt is preferable to that of the potassium salt[19], as, for example, in the decomposition of corundum. The sodium salt acts more quickly, and the double salts formed with aluminium, chromium and some other metals are more soluble than those formed with the potassium salt. The sodium salt also has the advantage that it may be used in procedures which subsequently employ perchloric acid. The potassium salt cannot be used in such cases owing to the low solubility of potassium perchlorate. A disadvantage of the sodium salt is that it has a greater tendency to crust over than the potassium salt, and the progress of the fusion cannot be so easily followed.

Sears and Quill[20] and Sears[21] have pointed out the necessity of paying proper attention to the proportions of sample and flux used in pyrosulphate fusions (due regard being paid to the nature of the sample,) and to the temperature at which the fusion is carried out. As a general rule, the temperature should be no greater than that required to maintain the flux in a fluid condition, and for a length of time sufficient only to dissolve the material.

Fusion with bisulphates and pyrosulphates can be carried out in either platinum or silica vessels. With platinum there is some attack on the metal, the amount of attack depending upon the temperature of the fusion and the time of contact of the fused salt with the platinum. This point must be borne in mind in any subsequent analysis of the fused mass. The use of silica vessels wherever possible is strongly advocated[22,23], especially if the fusion is a protracted one. Schoeller[24] says that the attack on silica (Vitreosil) crucibles by fused potassium bisulphate is practically negligible, and quotes a case of a silica glass crucible, which had already been in use a long time before being put under observation, that lost only 0·0052 g. after 32 fusions, an average of only 0·16 mg. per fusion. Platinum crucibles lose on an average 1–3 mg. per fusion. Moreover, the bisulphate melt does not foam when in contact with the non-metallic surface. An excellent summary of the behaviour of silica crucibles and silica apparatus generally towards fluxes and other reagents has been published[25].

The use of the acid fluorides is usually confined to the "opening-out" of the more siliceous materials, but is occasionally extended to other substances, for example, zircon, rather for assay purposes than for a complete analysis. The fluoride fluxes are nearly always potassium bifluoride (KHF_2) or ammonium bifluoride (NH_4HF_2). The normal ammonium salt NH_4F may also be used, but on heating it is decomposed with the formation of the acid salt :

$$2NH_4F \longrightarrow NH_4HF_2 + NH_3.$$

These fluxes cannot be used if silicon is to be determined accurately, but will provide a rough routine check on the silica content by a direct loss in weight. Therein lies one of their advantages, in that the silica is removed at the beginning of the analysis.

The temperature required for the fusion is very low, and the fusion operation is completed in much less time than with other fluxes. Fusions are carried out in platinum vessels and no attack on the platinum takes place. The volatility of certain metallic fluorides during the fusion must be borne in mind. If the temperature and duration of the fusion be kept at the absolute minimum, no loss of titanium or zirconium results[26]. Some applications of the use of these fluxes to several of the oxide bearing materials under discussion are described in Section 4.

Anhydrous borax ($Na_2B_4O_7$) is a very useful flux, and can be used to advantage in certain cases where the more common fluxes are relatively ineffective. Fusions with borax are carried out in platinum vessels, and there is a slight attack on the metal above 1,000° C. The molten salt is very viscous and it is recommended that a short stout rod of platinum should be kept in the crucible and used to stir the molten mass from time to time. The salt should be dehydrated before use. This can conveniently be done by first heating the crystallised salt gently in a platinum crucible until all moisture is expelled, and then increasing the temperature until fusion takes place. After cooling, the sample is placed upon the solidified melt and the decomposition operation completed.

Boric oxide (boric acid) has also been used as a flux, mainly for certain refractory silicates, with a view to determining their alkali content[27,28]. A full description of the boric oxide method of Jannasch and Heidenreich is given by Hillebrand[32]. It is claimed by Jannasch and Weber[29] that boric oxide causes complete expulsion of fluorine as boron trifluoride (BF_3), without any loss of silicon, when used as a flux for fluorine-containing substances, but as yet this claim has not been finally established[30]. About 10 parts of flux to 1 part of the very finely powdered material are required, and the final heating must be such as to fuse the mixture to a clear transparent melt. Alkali-free boric oxide can be prepared by several recrystallisations of a good quality commercial product. The purified crystals must be dehydrated before use ; this can be accomplished in the same manner as with borax. The anhydrous oxide is hygroscopic.

Both anhydrous borax and boric oxide are non-oxidising fluxes, and are used only for oxidised substances that are not volatile at the temperatures required for the fusion. In both cases the boron must, as a rule be removed before the usual analytical operations are carried out, but Hazel[31] states that this is not necessary : that with proper washing, the silica will not be contaminated with boron, and no interference is encountered in the "R_2O_3" group separation. It is generally recognised however, that if accurate results are to be obtained, it is necessary to remove the boron, for example, by volatilisation as the methyl ester, before proceeding with the analysis. Boric oxide has the advantage over borax in that no fixed alkali is introduced. As in the case of borax, there is a slight attack on the platinum vessel during the fusion.

In addition to the more common fluxes mentioned above, some other compounds have been used for decomposing silicates. A number of lead compounds were investigated by Jannasch and his co-workers, primarily with the object of determining the alkalies, in addition to other constituents, in one and the same portion of sample. These lead compounds were lead oxide (PbO)[33], lead carbonate[34] and lead chromate[35]. Basic bismuth nitrate[36] and bismuth oxide[37] have also been used. Today these fluxes find no application for decomposing any of the types of materials under consideration, and they will not be further discussed. The advantages and disadvantages in the use of these compounds are summarised by Hillebrand, Lundell, Bright and Hoffman[38].

Fusion with sodium amide ($NaNH_2$) has been employed by Petersen and Bergstrom[39] for the decomposition of a large variety of silicate materials. It is claimed that clays, feldspars, serpentine, fired refractories, glasses and bauxite are completely decomposed by fusion for two to three hours at 330° C. (in some cases the temperature may be much lower) in nickel vessels, and that less than 0·3 mg. of nickel passes into the fusion. Alundum is not decomposed. Zirconia is slowly and completely attacked by the flux after fusing for four hours at 330° C. It is necessary that the sample should be ground to pass a 200-mesh sieve. The authors (*loc. cit.*) give the following directions for carrying out this procedure :

The fusion is carried out in 100 ml. nickel crucibles, with the use of approximately 20 g. of the flux and 0·5 g. of the sample. Half of the sodium amide is first placed in the empty crucible and the sample is spread over the surface and then covered with the remainder of the flux. The crucible and its contents are placed within another nickel crucible of 150 ml. capacity, in case the fusion creeps out of the smaller crucible. The two crucibles are placed in a muffle furnace previously heated to the required temperature, and maintained at that temperature, (330° C. if the sample is of unknown material), for the specified period of time. A stream of ammonia gas is passed through the furnace during the fusion and subsequent cooling to room temperature. The inner

crucible and its contents are placed in a 500 ml. beaker containing 95% alcohol. Small quantities of water are added from time to time as the reaction subsides. The subsequent analysis is then carried out by the usual methods. Sodium amide may be purchased, or it may easily be prepared according to the directions of Petersen and Bergstrom. Its melting point is 210° C. The flux should not be used after it has been exposed to the atmosphere for any length of time, as there is then a danger of explosion. The main drawback to the use of this substance as a flux seems to be the necessity of carrying out the fusion in an atmosphere of ammonia.

In most procedures where decomposition with the aid of a flux is carried out, it has been, and still is, the common practice to use an amount of flux sufficient to give a fluid melt on heating, the exception to this being, of course, the J. Lawrence Smith method[40] of decomposing silicate materials for the determination of the alkalies, in which a mixture of calcium carbonate and ammonium chloride is used which forms a sinter but does not melt. This method of decomposition by the use of " sintering mixtures " is growing in favour, and some applications of various sintering mixtures will be described later. Mixtures such as calcium oxide—sodium carbonate, magnesium oxide—sodium carbonate—potassium carbonate (sometimes called Stead's tribasic flux[41]), barium oxide or carbonate—sodium carbonate, etc., have been used for a variety of refractory substances with more or less success. The main points regarding the use of these sintering mixtures are that the sample shall be in a sufficiently fine state of division, and that the correct temperature of heating for the particular type of material under investigation shall be used. This latter is usually in the neighbourhood of 1,200° C.

The tendency in recent years has been to reduce considerably the amount of flux (particularly when alkali carbonates are used) so as to avoid contaminating the resulting solution with large amounts of fixed salts. It was found by Finn and Kleketka[42] that by heating 0·5 g. of the sample with 0·6 g. of sodium carbonate at a temperature of about 875° C. for 2 hours, a large number of silicate materials could be readily decomposed, and the sintered product so formed was completely soluble in acid. There is an optimum time and temperature for each type of material. Bauxite, feldspar, burnt refractories, clays, quartz and siliceous bricks were successfully decomposed in this manner. Probably other types of materials could also be successfully decomposed by the proper adjustments of the relative amounts of sample and sodium carbonate used, and the time and temperature of sintering.

Hoffman[43] found that a large number of oxide-bearing materials could be successfully " opened-out " by heating 0·5 g. of the sample with 1·0 g. of sodium carbonate in a platinum vessel at 1,200° C. for 15 minutes, and extracting the melt in dilute hydrochloric acid (1 : 1). Feldspar, high alumina refractories, glass, limestone, clays, bauxite, cryolite (high in zirconia), and a wide range of silicate rocks and minerals were successfully decomposed by this treatment. Fused alumina and alundum cement were not satisfactorily decomposed. Small losses of platinum (1–2 mg. per determination) were reported when using this procedure. In carrying out this method, the same platinum vessel is used for the fusion of the sample, the solution of the melt, the evaporation to dryness and the ignition of the silica residue, with the consequent saving of much time.

C—Special Methods of Decomposition

There are a number of decomposition procedures of a special nature that are not so widely applicable as the methods usually employed. As a rule they only apply to the treatment of one or two specific materials, or to the determination of single constituents. It is proposed to discuss here the decomposition procedures employed for the determination of ferrous iron and of the alkali metals. Some other special methods of decomposition are described later in Section 4.

(*a*) *Ferrous Iron*

The " opening-out " of silicate and refractory materials for the purpose of determining ferrous iron has always been a problem for the chemist, and even now it is not satisfactorily or completely solved. Although the actual methods for the determination of ferrous iron are intimately connected with the method of decomposition employed, it is not proposed to discuss the methods themselves in detail. A resumé of the various methods of attack that have been proposed, together with their limitations, only will be given here. A more detailed discussion of earlier work as applied to natural silicates and minerals is given by Hillebrand, Lundell, Bright and Hoffman[44] and by Groves [45].

Until recent years, the only method used for attacking silicate and refractory materials for the determination of ferrous iron was based on that of Mitscherlich[46] later modified by Cooke[47] and by Pratt[48]. Mitscherlich decomposed the material with sulphuric acid in a sealed glass tube at 150°–200° C., and fairly good results can be obtained by this method if sulphides are absent. Allen[49] used hydrochloric acid instead of sulphuric acid in sealed tubes, but with no improvement in the results. Cooke and Pratt used a platinum crucible and a mixture of sulphuric and hydrofluoric acid, in the absence of air: Cooke used an atmosphere of carbon dioxide. The ferrous iron was titrated with potassium permanganate solution. These methods as they stand have several disadvantages which have an important bearing on the accuracy of the ferrous iron determination. The Mitscherlich method is limited in its application to those materials that are completely decomposed by sulphuric acid alone, and in the absence of sulphides and carbonaceous matter. Under these conditions the method approaches the ideal. A larger variety of substances are decomposed by a mixture of sulphuric and hydrofluoric acids, but some substances are very resistant to attack by this acid mixture, notably the spinels. This method of decomposition is also subject to the same limitations as the method of Mitscherlich. In the presence of hydrofluoric acid, there may also be some premature oxidation of the ferrous iron and, therefore, the effects of the free hydrofluoric acid must be annulled. This is usually effected by the addition of boric acid[50], which forms the harmless hydrofluoboric acid (HBF_4).

Some variations of the acid decomposition procedures that have been proposed are as follows.

Dougherty[51] decomposed acid steelmaking slags in a mixture of sulphuric and hydrofluoric acids, contained in a lead test tube, and in an atmosphere of carbon dioxide. Acid slags were also decomposed by Budaev and Shportenko[52] by boiling the slag sample with a mixture of 15 ml. of phosphoric acid, 85 ml. of dilute sulphuric acid (1 : 4) and 2 g. of pure, finely crushed calcium fluoride per 1 g. of sample. With basic slags, it is common practice to dissolve the sample, together with 1–2 g. of sodium

bicarbonate, directly in hydrochloric acid in a flask fitted with a Bunsen valve. Hydrofluoric acid may or may not be used, according to the material under investigation. With hydrochloric acid present, potassium dichromate is used for titrating the iron in place of potassium permanganate, together with a suitable oxidation-reduction indicator. In this latter procedure, no account is taken of any sulphide sulphur that may be present, and which could cause some reduction of the ferric iron present in the slag, and so tend to give a high value for the amount of ferrous iron. A procedure for overcoming this difficulty has been described by Quadrat[53].

Another variation of the acid decomposition procedure is that of Sarver[61], who used a mixture of hydrochloric, sulphuric and hydrofluoric acids to dissolve the sample contained in a platinum crucible and in an atmosphere of carbon dioxide. When decomposition was complete, as seen through a transparent plastic cover, which also carried a plastic tube for the introduction of the carbon dioxide, the solution was cooled to room temperature, a measured excess of potassium dichromate solution was added and the solution poured on to solid boric acid. The excess of potassium dichromate was then titrated with ferrous sulphate, using diphenylamine as indicator. Soule[62] decomposed the sample with hydrofluoric and sulphuric acids in a quartz flask, so that the reaction could readily be observed and no transference of the solution for the titration was necessary. A correction factor per gram of glass dissolved was applied. In another paper, Soule[63] determined ferrous iron in magnetites and silicate materials by solution of the sample in hydrochloric and hydrofluoric acids in a Pyrex flask filled with carbon dioxide, and titrated the ferrous iron potentiometrically with a dilute solution of ceric sulphate. Schollenberger[65] also used the acid decomposition procedures, and pointed out that the presence of hydrofluoric acid is actually an advantage if the ferrous iron is titrated with potassium dichromate, using diphenylamine as indicator. Many other investigators have used the acid decomposition procedure, in different forms, for decomposing the various oxide-bearing materials for the determination of ferrous iron[64,67].

A number of devices have been described, designed to overcome errors caused by the premature oxidation of the ferrous iron. Smirnov and Aidinjan[54] decomposed the sample with hydrofluoric and sulphuric acids under a layer of toluene. Schein[55] determined ferrous oxide in chromite by treating the sample with a mixture of sulphuric and phosphoric acids containing a known amount of 5-valent vanadium at 370° C. The excess of oxidised vanadium was titrated with ferrous sulphate. Later, Balyuk and Mirak'yan[56] modified Schein's method and extended it to the determination of ferrous oxide in chrome-magnesite refractories. The same principle has been adopted by Samanta and Sen[57] and by Ishibashi and Kusaka[58], for decomposing chrome-refractories and miscellaneous silicates, respectively.

Rowledge[59], in an attempt to overcome the difficulties associated with the incomplete decomposition of various silicates by acids, carried out much experimental work on the use of fluxes for this purpose, and finally found sodium metafluoborate, $(NaF)_2B_2O_3$, to be the most suitable. The sample is fused for 15 minutes at about 950° C. in a sealed Pyrex tube with six times its weight of flux: the cooled melt is dissolved in dilute sulphuric acid, and the solution titrated with potassium permanganate. The flux is prepared by heating together, in a platinum dish, a mixture of 2 parts of anhydrous sodium fluoride and 1 part of anhydrous boric oxide (boric acid may also be used) in molecular proportion, at a temperature between 750° and 1,050° C., until a clear melt results. It is then ground and stored ready for use. An improvement on this method has been described by Groves[45], who carries out the fusion in a platinum boat contained in a tube furnace, and solution of the melt in sulphuric acid, all in an atmosphere of carbon dioxide. According to Groves (*loc.cit.*) this solution is relatively stable compared with mixed sulphuric and hydrofluoric acid solutions, and is not prone to rapid oxidation in the air at room temperature. The behaviour of sulphides in this procedure has not yet been fully investigated.

Another method of decomposition is that proposed by Hey[60]. In this method the sample is treated in a platinum vessel with a mixture of hydrochloric acid, hydrofluoric acid and iodine monochloride. Decomposition takes place at room temperature. When decomposition is complete, the solution is titrated with potassium iodate solution using carbon tetrachloride as the indicator.

The reactions taking place are as follows :

$$2ICl + 2Fe^{++} \longrightarrow I_2 + 2Cl^- + 2Fe^{+++}$$

$$\text{and } 2I_2 + KIO_3 + 6HCl \longrightarrow KCl + 5ICl + 3H_2O$$

the complete reaction being

$$4Fe^{++} + KIO_3 + 6HCl \longrightarrow KCl + ICl + 3H_2O + 4Cl^- + 4Fe^{+++}$$

This method is applicable to those materials which are also decomposed by mixed sulphuric and hydrofluoric acids, and it has the added advantages that there is no premature oxidation of the ferrous iron, and that the resulting solutions are quite stable in air. Hey has also adapted the method of Rowledge (*loc.cit.*) to the determination of ferrous iron in refractory silicates on a micro-scale. According to Groves (*loc.cit.*), employing the initial decomposition used by Rowledge, treating the melt with the iodine chloride—hydrochloric acid solution and titrating with potassium iodate, affords probably the best procedure so far described for dealing with this difficult problem.

A totally different method has been put forward by Seil[66] for decomposing chromite for the purpose of determining the ferrous iron. The chromite sample is attacked with sulphuric acid in phosphoric acid at 350° C., in an atmosphere of carbon dioxide and under reduced pressure. The following reaction, which is quantitative, takes place :—

$$2Cr_2O_3FeO + 10H_2SO_4 \longrightarrow 2Cr_2(SO_4)_3 + Fe_3(SO_4)_3 + 10H_2O + 8O_2$$

The evolved sulphur dioxide is absorbed in a known amount of a standard solution of potassium dichromate, the excess of which is determined by titration with iodide and thiosulphate. A special apparatus, which is rather elaborate, is required, and the material must be very finely powdered. The residual acid solution is suitable for the determination of the chromium in the sample.

(*b*) *Alkali Metals*

The importance of alkalies in the raw materials, and the effects the alkalies have on the prepared refractory materials when in service, are too well known to be repeated. Methods used for the determination of these elements are, therefore, important.

The methods used for the decomposition of oxide-bearing materials for the determination of the alkali

metals are based almost entirely on two procedures. One, the oldest procedure, is due to Berzelius[68], and involves an acid decomposition with sulphuric and hydrofluoric acids, the removal of all metals except the alkalies, and the conversion of the alkali sulphates to chlorides. The other procedure is that devised and developed by J. L. Smith[40], in which the material is decomposed by heating with a mixture of ammonium chloride and calcium carbonate. The alkali metals are converted directly to chlorides which can be extracted by water. From time to time, modifications to the two methods have been proposed, but it is doubtful if any real advance has been made on the original procedures. The modifications that have been introduced have mainly been for the purpose of rendering the subsequent operations for the removal of the other elements easier and more complete, rather than in the mode of decomposition.

Variations of the acid decomposition procedure have been aimed chiefly at the elimination of the sulphate and the fluoride, which cause complications later on in the analysis. Sulphate must be removed first if the solution is to be used for the determination of potassium, or for the determination of sodium and potassium by weighing as the combined chlorides. Methods for the removal of the fluoride without the introduction of sulphate have also been tried. Boiling with concentrated perchloric acid is said not to expel completely all the fluorine, probably because of the great stability of the fluoaluminate ion (AlF_6^{---}).

Koenig[69] decomposed feldspars with hydrofluoric acid alone, and separated the heavy metals, magnesium, fluorine and residual silicon by precipitation with calcium oxide. This method was, however, severely criticised by Willard and his co-workers[70]. In another method Willard, Liggett and Diehl[70] decomposed the sample with a mixture of hydrofluoric and perchloric acids and, after the elimination of most of the fluorine by evaporation to fumes of perchloric acid, the remaining fluorine was removed by volatilisation as hydrofluosilicic acid (H_2SiF_6), as in the method of Willard and Winter for the determination of fluorine. This is an excellent approach to the determination of potassium only in silicate materials. If sodium is to be determined, the distillation is omitted and the sodium determined directly by precipitation as the triple acetate. Marvin and Woolaver[72] also decomposed the sample with a mixture of hydrofluoric and perchloric acids, removed the excess of hydrofluoric acid by fuming in the usual way, and subjected the resulting perchlorates to thermal decomposition. The perchlorates of sodium, potassium and calcium give the corresponding chlorides, whereas the perchlorates of magnesium, iron and aluminium form the corresponding oxides[73]. A simple extraction of the decomposed perchlorates with hot water, made slightly alkaline with ammonium hydroxide, gives a solution containing essentially only sodium, potassium and calcium as chlorides. This procedure is not applicable however, if sulphates and phosphates are present.

Other modifications of lesser importance that have been proposed in acid decomposition procedures are those of Low[74], who eliminated the excess of sulphuric acid by heating until fumes nearly ceased, and of Krishnayya[75], who heated the sulphate residue to complete dryness, leaving a residue of oxides.

In his earlier studies on the decomposition of silicates, Smith[76] investigated a number of fluxes to assist the calcium oxide fusion. Twenty years later, Smith devised the procedure used so extensively today. In this procedure the sample is intimately ground with an equal weight of ammonium chloride and eight times its weight of calcium carbonate. If much iron is present, the amount of calcium carbonate should be increased. The decomposition is carried out in a special elongated platinum crucible (called the J. Lawrence Smith crucible) having a well-fitting cap. According to Groves[45], there is no necessity to use the specially shaped crucible usually advocated; a crucible of ordinary pattern is quite satisfactory if its upper part is protected from the flame by inserting it upright through a well-fitting hole in an asbestos board so that only about one third of it projects below into the flame. Neither is there any necessity for the lid to be kept cool by means of a beaker of cold water placed upon it. The heating is carried out very slowly at first, until the odour of ammonia can no longer be detected and the chloride ion has been fixed as calcium chloride, after which the charge is ignited strongly for 60–90 minutes, according to the type of material under investigation. The reactions which take place when this mixture is heated are as follows :

$$CaCO_3 + 2NH_4Cl \longrightarrow CaCl_2 + 2NH_3 + H_2O + CO_2$$

$$\text{and } CaCO_3 \longrightarrow CaO + CO_2$$

From the sintered cake thus obtained, the alkalies are extracted as water-soluble cholorides. For the success of this decomposition, the sample must be very finely ground and thoroughly mixed with the flux. Lamar, Hazel and O'Leary[77] point out that for the successful decomposition of difficultly decomposable substances, such as highly aluminous materials, the samples should be ground to pass at least 200 mesh, a temperature of between 1,000° and 1100° C. should be maintained for at least 90 minutes after the ammonia has been driven off, and the ammonium chloride and calcium carbonate should have been intimately mixed together by ball-milling before compounding with the sample. Under conditions such as these a second fusion is not usually necessary. There is no loss of alkali by volatilisation, neither is there any difficulty in leaching out the cake with water if the recommendation of Mellor[6] is followed of adding not more than 2 ml. of water to the cake and allowing the slaking of the lime to take place for 10–15 minutes before adding more water.

A few modifications of the J. L. Smith procedure have been reported in the literature. Makinen[78] fused the finely-ground sample with calcium chloride alone, and claimed to get a slightly more perfect attack. Buttmer[79] proposed the use of barium carbonate instead of calcium carbonate, obtaining more precise but apparently low results. Scholes and Wessels[80] sinter the sample with a mixture of calcium carbonate and calcium chloride, prepared by treating calcium carbonate with a deficiency of hydrochloric acid, and heating at 800°—900° C. Stevens[81] substitutes 1 g. of hydrated barium chloride for the 0·5 g. of ammonium chloride normally used in the Smith method, and claims that the method is equal to that of Smith in the completeness of alkali extraction, but the modification allows a saving of time and automatically removes any sulphate present in the sample. In addition, the very slow preliminary heating necessary in the Smith procedure to expel ammonia is eliminated.

Reference has already been made[27,28] to the use of boric oxide and boric acid as fluxes for decomposing certain refractory substances prior to determining their alkali content. Although not much used today, this

procedure has been employed by Archibald and McLeod[82] as a means of decomposing alumina for the determination of sodium oxide. For a 0·5 g. of sample of alumina, 0·85 g. of boric oxide or 1–1·5 g. of boric acid is recommended. The mixture is heated in a covered platinum crucible over a low flame for about 5 minutes. The temperature is then gradually increased to the full heat of the flame and the heating continued for a further 5 minutes. The sintered mass is extracted with water, the extract acidified with a few drops of hydrochloric acid and the solution boiled to break up the sinter. From the filtered solution, the sodium may be determined by any standard procedure.

For the determination of sodium in calcined alumina and aluminium hydrates, Jackson[83] employed a decomposition procedure embodying heating of the alumina samples with hydrochloric acid in sealed tubes for 5 hours at 250° C. Under these conditions 100% decomposition was obtained. It was also found that aluminium mono- and tri-hydrates were readily dissolved under pressure by heating with an excess of hydrochloric acid for 1–2 hours at 200° C., and that complete extraction of the alkali was also obtained from fused alumina under these conditions. After filtration and removal of excess acid, the sodium can be determined as the triple acetate. Jackson further states that extraction of sodium from alumina with dilute hydrochloric acid (1 : 1), in all-silica Soxhlet apparatus, gave a solution containing all the sodium, together with most of the iron and a small amount of aluminium, after boiling for 24 hours.

to be concluded

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Physical Society Exhibition

(*continued from page 54*)

The following facilities are provided by the apparatus :

(1) Positive, automatic scanning of sheet, billet, plate and other specimens of simple cross-section.

(2) High speed scanning with certainty of detection of flaws.

(3) Instantaneous and permanent recording on paper of flaws.

(4) Simplicity of correlation of the traces on the recording paper with specific plan positions on the specimen.

(5) Automatic compensation for variations in acoustic contact between probe and specimen and other variables affecting sensitivity.

(6) A flaw detection warning system whereby a visual or audible signal is given when flaw echoes above a predetermined magnitude are detected.

(7) A circuit failure alarm system whereby a visual or audible signal is given when a degree of acoustic contact or circuit efficiency falls below a predetermined standard. This signal may be supplemented by an automatic "cut-out" arrangement.

The apparatus, as demonstrated, uses a modified combined vertical probe, housing the transmitter and receiver elements in a single head. Surface friction is minimised by mounting the probe on special skids, thus protecting it from damage and permitting high speed scanning. A constant distance between the surface of the sample and the probe is maintained as far as possible, and complete acoustic contact is achieved by feeding a continuous flow of water into the gap.

Exhibits of Metallurgical Interest at the Physical Society Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Balances

A NUMBER of balances were shown by L. Oertling, Ltd., including two riderless micro-balances and two semi-automatic balances. Since their introduction about 50 years ago, all microchemical balances have of necessity been fitted with a rider mechanism. For some time evidence has been accumulating that the use of the rider principle is a serious limitation to the accuracy which can be obtained from microchemical balances.

Oertling riderless micro-balance

New instruments have been developed, believed to be the first of their kind, which enable micro- and semi-micro weighings to be made without the use of a rider. Model 146 has a sensitivity of 0·02 microgram per division, with a capacity of 30 g., and Model 147 has a sensitivity of 0·002 microgram per division, with a capacity of 20 g. Improved accuracy and quicker weighing are the principal advantages of the new designs. All the best features of Oertling micro-balance design are retained and the opportunity has been taken to house the instrument in a case of contemporary style.

Designed to meet a long-felt need for a very rapid balance for preparatory weighing, Models 70 and 71 semi-automatic balances are exceptionally robust and quick in operation. Both models have a capacity of 2 kg. in each pan and are oil-damped to give almost instantaneous reading. Model 70 has a sensitivity of 50 mg. per division with a range of 5 g. on the scale. Model 71 has a sensitivity of 100 mg. per division with a range of 10 g. on the scale.

Automatic Ultrasonic Flaw Recording

SOME examinations using ultrasonic flaw detection require a permanent record to be made. When testing long welded seams, for example, it is necessary to know the exact position of any flaw. Kelvin Hughes engineers have developed and produced equipment which not only completes an automatic and rapid examination of the sample under test, but simultaneously presents a permanent record on paper of the examination. Warning and alarm systems are incorporated, and the faciltiies offered by the equipment reduce human participation in the detection and interpretation of flaw echoes to a minimum.

The automatic scanning and recording equipment is, very generally, a linking of the flaw detector with an automatic pen recorder. Produced originally in collaboration with a leading boiler manufacturer, it was designed at first for the examination of long welds in large pressure vessels, as an alternative to, or to supplement, X-ray examination. Its field of application is now, however, very much wider.

A gantry moves the probes along the investigation route at a fixed speed, and the automatic pen recorder traces the signals from the receiving probe. If a flaw is detected, the amplitude of the recording pen stroke is in direct proportion to the size of the flaw, and its position can be found easily from the recorder paper. It is claimed that this method of recording will show considerable savings in both time and materials when compared with, for example, X-ray photography.

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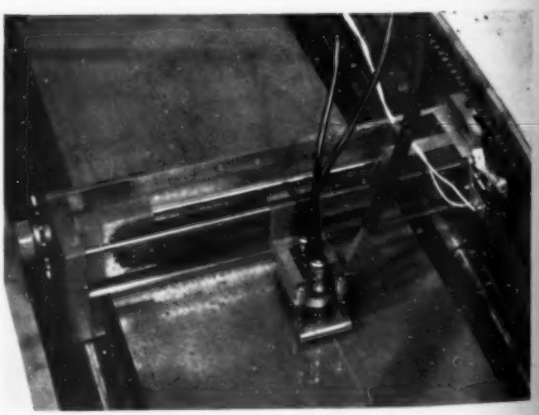

Automatic scanning and recording equipment